OIL AND GAS FINDING COSTS IN ALBERTA: 1970-1985

JANICE E. PASAY

CANADIAN ENERGY RESEARCH INSTITUTE

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Preface

This report is an update of CERI Research Report 85-2, Estimated Petroleum Finding Costs in Alberta: 1970-1983. The work for the current report was conducted in the Fall of 1986 and completed in early January of 1987. It was undertaken by Janice L. Pasay, an economist with CERI Energy Research Ltd., a separate organization which undertakes consulting and contract research assignments in energy economics.

The author would like to express her gratitude to the four member advisory committee of government, industry, and industry association representatives for their input into the study. Thanks are also due to the many industry representatives who provided valuable time and expertise. The author herself, however, is solely responsible for the conclusions drawn and for any errors or omissions which remain.

Special thanks are extended to Adele Crowley for her computer programming support and to John Trudeau for his quality graphics work. The excellent word processing of Shirley Ingstrup, Janice Morrison, and Donna Zimmerman are also appreciated.

Finally, the author would like to thank Anthony Reinsch, Manager of Research for the Canadian Energy Research Institute, for his patience and support throughout the course of the work.

EXECUTIVE SUMMARY

The primary purpose of this report is to provide estimates of hydrocarbon finding costs for Alberta for the 1970 to 1985 period. The methodology employed and the major results are summarized below.

Definitions and Assumptions

- For the purpose of this report, finding costs are defined as total exploration expenditures divided by fully appreciated reserves.

- Larger pool reserves discovered between 1981 and 1985 are multiplied by an appreciation rate to estimate fully appreciated reserves. Smaller pool reserves discovered in these years and estimates of reserves discovered in earlier years are assumed to be fully appreciated.

- Pentanes plus and natural gas liquids are implicitly included in the analysis by using raw as opposed to marketable natural gas reserves. Sulphur reserves are included in the analysis to the extent that they constitute a part of raw natural gas reserves.

Preferred Case Results

- Preferred case finding costs are calculated on the basis of the most appropriate assumptions and, therefore, are most representative of average industry finding costs. Separate preferred case finding costs are calculated for crude oil and natural gas based on a measure of exploratory intent. Low case and high case results are derived by including 50 percent and 100 percent of land expenditures, respectively, to account for the fact that some land expenditures are attributable to development activity.

- Alberta preferred case crude oil finding costs demonstrate a general increasing trend over the period. The 1985 3-year moving averages range from about $8 to $9 per barrel.

- Alberta preferred case natural gas finding costs also increase over the period, reaching 50 cents to 60 cents per thousand cubic feet in 1985 on a 3-year moving average basis.

Base Case and Sensitivity Case Results

- In the base case and sensitivity cases, raw natural gas is converted to crude oil equivalents to calculate crude oil equivalent finding costs. An historical price equivalence of 9.4 thousand cubic feet of natural gas to one barrel of crude oil is used in the base case.

- Base case crude oil equivalent finding costs demonstrate a generally increasing trend on a 3-year moving average basis, peaking at about $8.10 per barrel in both 1981 and 1985, measured in constant 1985 dollars. The upward trend is emphasized in the 5-year moving average results.

- Six sensitivity cases illustrate the importance of the underlying assumptions in calculating finding costs. The results indicate that, of all the sensitivities presented, changes in the crude oil equivalence conversion rate and the reserves data base have the greatest impact on the base case results.

- Three-year moving average base case and selected sensitivity case results are presented below in 1985 constant dollars per barrel of oil equivalent:

Year	Base Case	Energy Equivalence Conversion	No Reserves Appreciation	Alternative Gas Reserves Data Base
1975	4.10	2.80	4.10	4.40
1980	6.60	4.80	6.60	6.10
1985	8.10	6.80	9.60	5.40

Extensions to the Base Case Analysis

- Separate finding costs are calculated for crude oil and natural gas by dividing total exploration expenditures between the two hydrocarbons using an estimate of exploratory intent based on successful exploratory drilling footage. Crude oil finding costs vary throughout the period, peaking in 1976 and 1981 but generally increasing over the period on a 3-year moving average basis. Natural gas finding costs show a clearer upward trend.

- The second extension accounts for the time element included in the exploratory process by lagging land expenditures by two years and

geological and geophysical expenditures by one year. The 3-year moving average results follow the same trend as the base case.

- Three-year moving average results for selected years for the extensions to the base case are presented below in 1985 constant dollars:

Year	Crude Oil ($/bbl)	Natural Gas ($/Mcf)	Lagged Expenditures ($/BOE)
1975	4.50	0.40	3.90
1980	4.80	0.80	5.50
1985	7.40	1.00	8.10

Alberta Finding Cost Trends

- Based on lower geological, geophysical, and drilling activity levels in 1986 compared with 1985 and proportionately greater decreases in the costs associated with these activities, 1986 finding costs could be lower if reserve additions and success rates remain constant. However, in light of the current poor economics in the industry, recoverable reserve estimates for recent years' discoveries may be high which could offset a potential decline in finding costs in 1986. This fact could also result in actual finding costs for the most recent years being higher than the estimates presented in this report, which would emphasize the general upward trend evident in the results.

Qualifications to the Results

- The finding cost results presented in this report must be interpreted only within the context of the methodology and assumptions employed. Comparisons with other finding cost estimates must also take into consideration any differences in methodology, data sources, and/or assumptions.

- The finding cost estimates presented serve as an industry yardstick against which companies in the oil and gas industry can measure their own finding costs. Although the results are presented in dollars and cents, distinctions should not be made to that level of precision. The overall trend is the most significant result.

Chapter 1

INTRODUCTION

In October of 1985, the Canadian Energy Research Institute published Research Report 85-2, Estimated Petroleum Finding Costs in Alberta: 1970-1983. The report provided a methodology for calculating finding costs as well as historical finding cost results for Alberta for the period 1970 to 1983. The report was well received and many requests for an update have been made since its release. The current report is that update.

1.1 Study Objectives

The report has two primary objectives. The first is to refine the methodology and assumptions employed in the earlier report in light of data base changes and subsequent analysis. For example, the Canadian Petroleum Association (CPA) incorporated small crude oil and natural gas pools data from the Alberta Energy Resources Conservation Board (ERCB) in their reserves data for the first time in 1984, creating a break in the data series which must be addressed if these data are to be used.

The second task is to provide historical finding costs for Alberta for the 1970 to 1985 period. The base case results are presented on a barrel of oil equivalent (BOE) basis. Sensitivities to the base case are also provided in which key variables are altered. Two extensions to the base case results provide estimates of separate crude oil and natural gas finding costs, and finding costs with time-lagged expenditures. Finally, preferred case finding costs are calculated using the most appropriate sensitivity and extension case assumptions.

1.2 Study Organization

Chapter 2 outlines the methodology and assumptions which form the basis for the finding cost results. The chapter also discusses methodological problems and the limitations they place on the results. Finally, the assumptions of the earlier report are compared with those

of the current report to determine the underlying causes for any differences in the results. Chapter 3 presents the crude oil equivalent base case and sensitivity case results. The extensions to the base case analysis are provided in Chapter 4. Chapter 5 includes a summary of the results and a discussion of the preferred case finding costs.

Appendices A and B provide detailed tables of the background data and the base case and sensitivity case finding cost results, respectively. The results for the extensions to the base case are given in Appendix C. Appendix D presents the preferred case finding cost results.

Chapter 2

METHODOLOGY AND ASSUMPTIONS

2.1 Methodological Problems

Calculating finding costs is, at a glance, a relatively simple task: divide reserves discovered by the costs incurred in discovering those reserves. However, several difficulties arise in quantifying the appropriate expenditures and reserves and then matching them over time.

The first concern is to determine the relevant expenditures involved in discovering reserves. For example, although land expenditures are required to find hydrocarbon reserves, some land expenditures result from development activity which does not actually find new reserves. A further difficulty is present in that expenditure data for crude oil and natural gas exploration are available only on an aggregate basis. Thus, some measure of exploratory intent must be applied to the aggregate expenditure data in order to estimate the portion of total expenditures attributable to each hydrocarbon.

The second element in calculating finding costs is the reserves discovered. Quantifying the reserves discovered as a result of the relevant exploration expenditures is complicated by the fact that the initial reserves estimate typically understates the true size of the discovery. Some allowance must be made so that finding costs are calculated using the estimated true size of the discovery.

The final difficulty inherent in finding cost calculations is to match the expenditures incurred over time with the reserves discovered. For example, land expenditures can occur several years before the discovery or, in some cases, in the same year. Similarly, geological and geophysical expenditures are incurred at differing periods prior to a given reserves discovery.

The significance of the methodology and assumptions employed to compensate for these difficulties is tested by first developing a base case and then changing various aspects of the primary methodology and assumptions in several sensitivity cases and in two extensions to

the base case analysis. Preferred case finding costs are also calculated, based on the most appropriate assumptions. Table 2.1 summarizes the major definitions and assumptions used.

The methodology and assumptions used are presented not as the only possible means to calculate finding costs but to provide a context for the finding cost results presented thereafter. For this reason, the results should be interpreted strictly within the confines of the methodology and assumptions used.

2.2 Definitions and Assumptions

2.2.1 Finding Costs

As previously indicated, hydrocarbon finding costs are calculated by dividing the cost of finding hydrocarbon reserves by the reserves found. In the base case analysis, the expenditures incurred in each year are assumed to apply to the reserves discovered in that year. Finding costs with time-lagged land expenditures and geological and geophysical expenditures are presented in Chapter 4 as an extension to the base case analysis.

Finding costs are calculated on a yearly basis as well as on the basis of 3-, 5-, and 7-year moving averages. The moving averages are attributed to the last year included so as to provide a finding cost estimate for 1985. Thus, 3-year moving average finding costs for 1985 are based on data for the years 1983, 1984, and 1985. The discussion in the text concentrates on the 3-year moving average results since the overall trend in finding costs is of greater significance than the year-by-year fluctuations.

The base case results reported are based on Canadian Petroleum Association (CPA) expenditure and reserves data. Only exploration expenditures are employed in calculating finding costs. Development expenditures such as development drilling, production facilities, and natural gas plants contribute to the delineation of the true size of the reserves and to their producibility, thereby improving the initial reserves estimates while not actually adding reserves to the initial discovery.

Exploration expenditures include geological and geophysical, land, and exploration drilling expenditures. Each type of expenditure is converted to 1985 constant dollars using the appropriate CPA cost

TABLE 2.1

DEFINITIONS AND ASSUMPTIONS

Term	Definition	Calculated/Estimated As
Finding Cost	Total exploration costs in a given year divided by fully appreciated reserves discovered in that year.	(Total Exploration Expd.) / (Crude + Raw Natural Gas Reserves x Appreciation Rate)
Reserves Appreciation Rate	The amount by which initial hydrocarbon reserves discoveries are expected to increase over time.	(Outlined in Tables A.4 and A.5)
Crude Oil Equivalence	The rate at which raw natural gas reserves are converted to crude oil equivalent reserves.	(1) Base Case: (Price Equivalence) 9.4 Mcf = 1 barrel (2) Energy Equivalence: 6 Mcf = 1 barrel (3) Netback Equivalence: 18 Mcf = 1 barrel
Exploratory Intent (Oil)	The percentage of total exploratory activity attributable to finding crude oil.	(Total Successful Crude Oil Metres Drilled) / (Total Successful Exploratory Metres Drilled)

SOURCE: CERI Energy Research Limited.

index and then reaggregated to calculate total 1985 constant dollar exploration expenditures (see Tables A.1 to A.3). As suggested by the CPA, land expenditures are converted to 1985 constant dollar expenditures using the exploration and development drilling index.

Initial established reserves dated back to the year of discovery are used in the denominator in the finding cost calculation.[1] Reserves estimates for the most recent years are revised upwards to account for expected future reserves appreciation. The calculation and application of reserves appreciation rates are discussed in the next section.

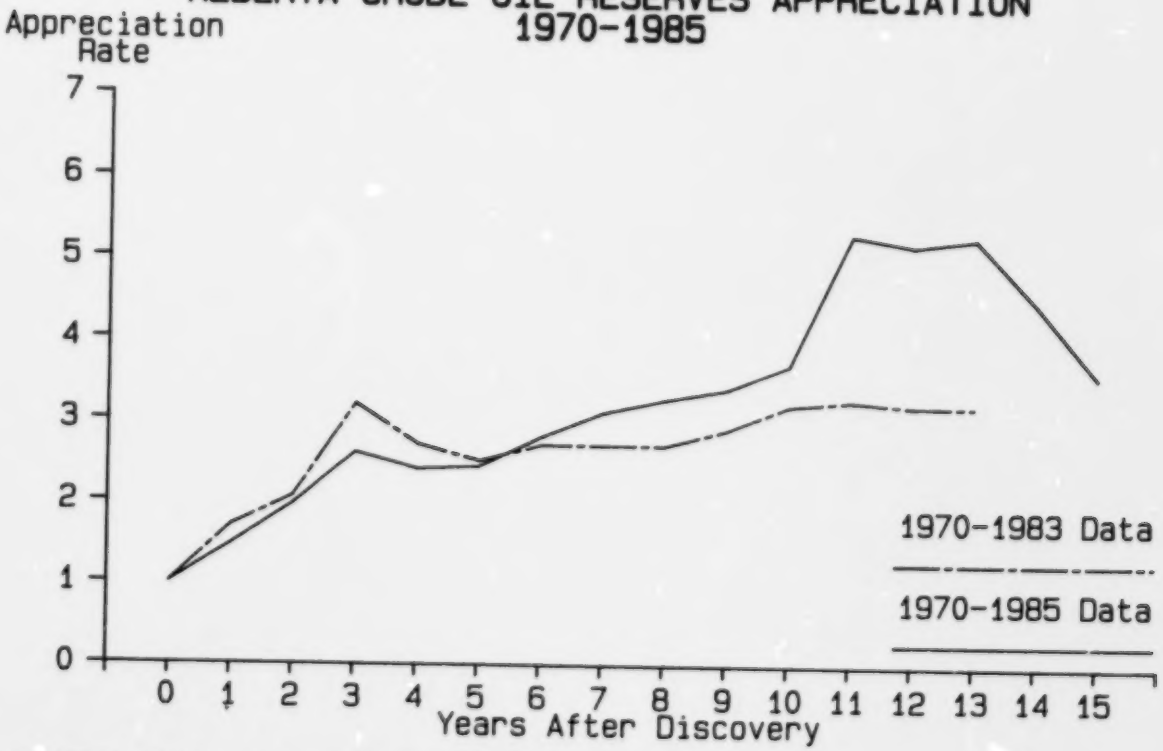
2.2.2 Reserves Appreciation

Reserves appreciation is the process by which the true size of an initial reserves discovery is determined over time. Fully appreciated reserves must be employed in finding cost calculations so as to match expenditures with the reserves actually found. Dividing exploration expenditures in a given year by only the initial estimate of the reserves discovered in that year would overstate actual finding costs.

Appreciation rates for Alberta crude oil and raw natural gas are calculated in Tables A.4 and A.5, respectively. First, appreciation factors for each year are calculated by dividing the total reserves estimates one year after discovery by the total initial reserves estimates; then, the total reserves estimates two years after discovery by the total reserves estimates one year after discovery; and so on. The appreciation factors thus calculated are then compounded (multiplied) over the entire period to derive the total appreciation rate applicable to each year's reserves estimate.[2] The maximum appreciation rate is applied to the most recent year's reserves (i.e., to the initial reserves estimate of the most recent year). Lower appreciation rates are applied to the reserves estimates of preceding years as some reserves appreciation would already be included in reserves estimates for earlier years. The further back in time that the reserves were discovered, the more reserves appreciation would already be included in the most recent estimate of the total reserves discovered and the lower would be the applicable reserves appreciation rate.

Appreciation rates obtained from the 1970 to 1985 CPA data are considerably higher than those calculated in the previous report using data from 1970 to 1983 (see Figures 2.1 and 2.2). This is contrary to

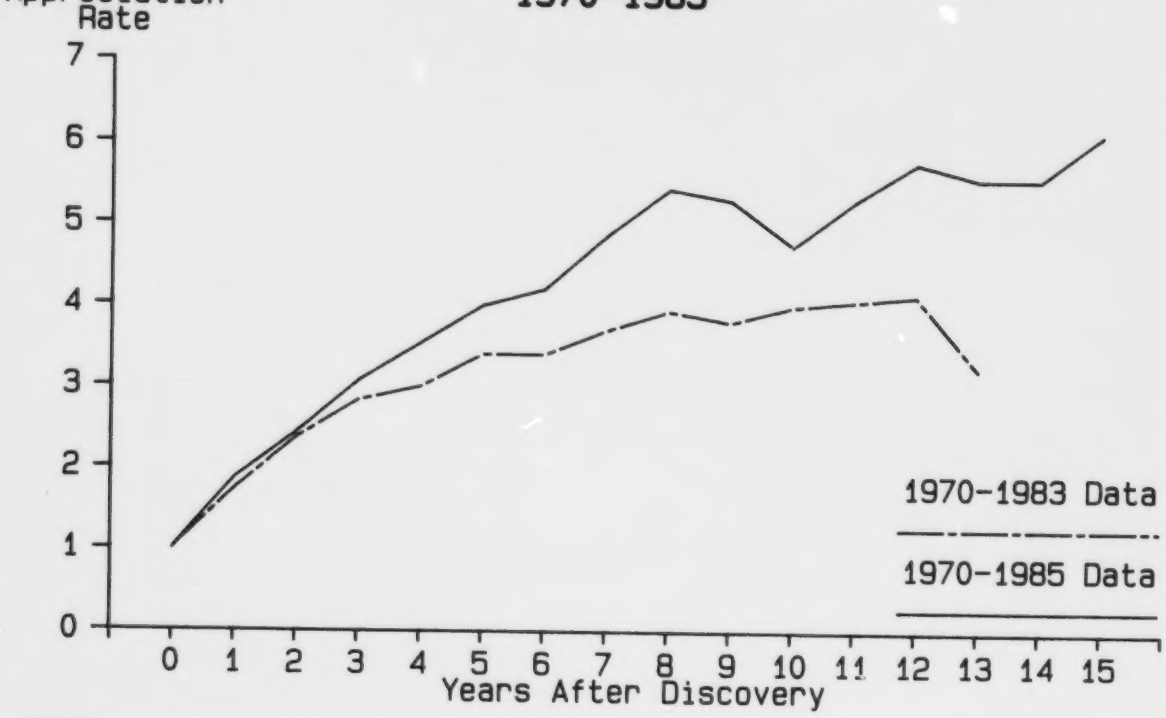
FIGURE 2.1
ALBERTA CRUDE OIL RESERVES APPRECIATION
1970-1985



SOURCES: Table A.4 and Canadian Energy Research Institute.

FIGURE 2.2

ALBERTA NATURAL GAS RESERVES APPRECIATION
1970-1985



SOURCES: Table A.5 and Canadian Energy Research Institute.

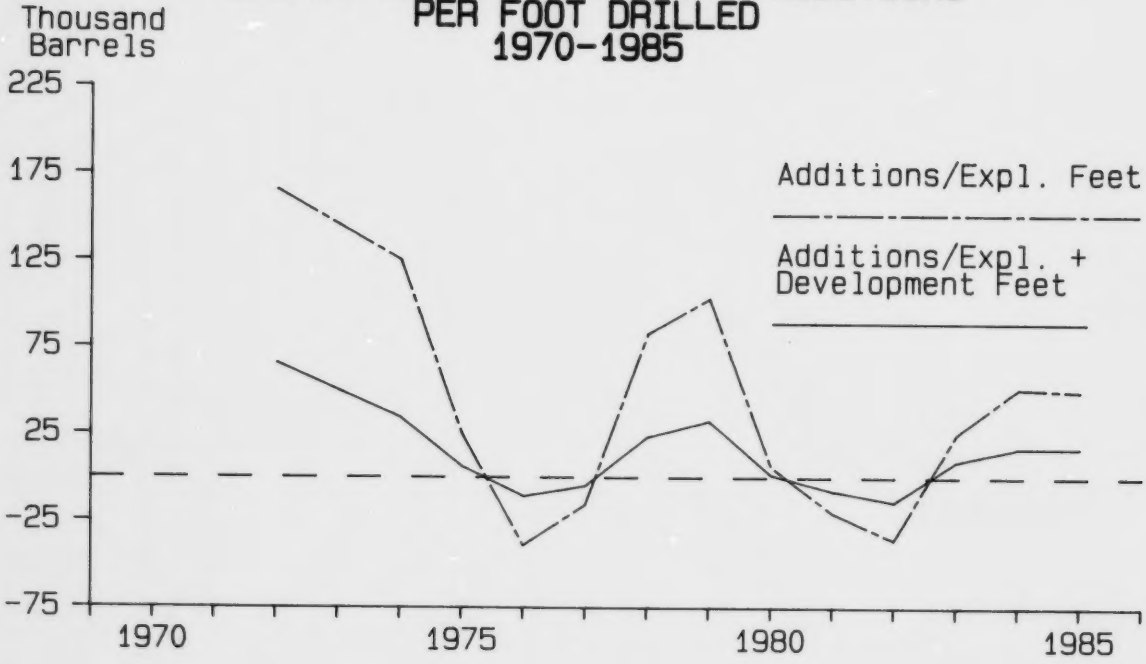
the expected trend in appreciation rates. Appreciation rates calculated from more recent years' reserves data are expected to be lower than for earlier years since both reserve additions per foot drilled and the average pool size of discoveries have generally fallen over time (see Figures 2.3 to 2.6). This is particularly true for crude oil reserves. Crude oil reserve additions per foot drilled in 1985 were only 13 percent of the 1970 value, and only 27 percent of the 1972 value on a 3-year moving average basis. Although natural gas reserve additions per foot drilled trended upward to 1984 and 1985, the average pool size of initial discoveries has fallen for both crude oil and natural gas: 17 percent and 75 percent, respectively, on a 3-year moving average basis.

The fact that the appreciation rates calculated from the 1970 to 1985 data are higher than those calculated from the 1970 to 1983 data is accounted for by the inclusion by the CPA as of 1984 of the ERCB small pool reserves figures in their total reserves estimates. The small pool reserves were added in by year of discovery, but only in the 1984 and 1985 data. Since the initial year and the subsequent years' estimates of pools discovered before 1984 were not adjusted to include these small pool reserves until 1984, the appreciation rates calculated from the 1970 to 1985 data are not as accurate as those using the 1970 to 1983 data. Thus, the appreciation rates used in this report were estimated from the appreciation curves for the 1970 to 1983 period.

As previously mentioned, the initial established reserves by year of discovery now reported by the CPA include larger pool reserves which are reviewed by the CPA and small pool reserves which are reviewed by the ERCB. Since small pools generally do not appreciate, only the large pool reserves reviewed by the CPA are "appreciable." Therefore, appreciation rates are applied only to that portion of total initial established reserves reported by the CPA that were reviewed by the CPA (see Table A.8). The small pool reserves (less than or equal to 300,000 cubic metres of crude oil, and less than or equal to 600 million cubic metres of natural gas) are not appreciated. For example, all the reserves discovered in 1985 were small pool reserves so that no appreciation was applied to 1985 reserves.

As evident from the 1970 to 1983 data curves in Figures 2.1 and 2.2, most reserves appreciation occurs within the first 5 years after discovery. Thus, appreciation rates are applied only to reserves discovered from 1981 to 1985. Reserves discovered from 1970 to 1980

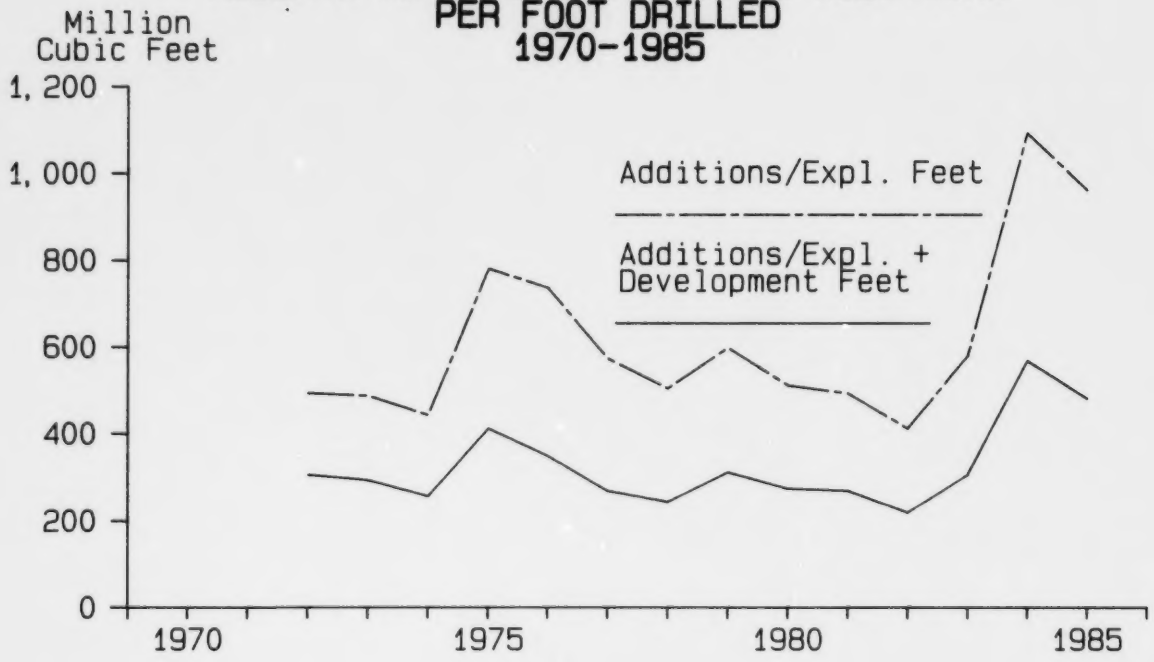
FIGURE 2.3
ALBERTA CRUDE OIL RESERVE ADDITIONS PER FOOT DRILLED 1970-1985



SOURCE: Table A.6.

Note: Three-year moving averages.

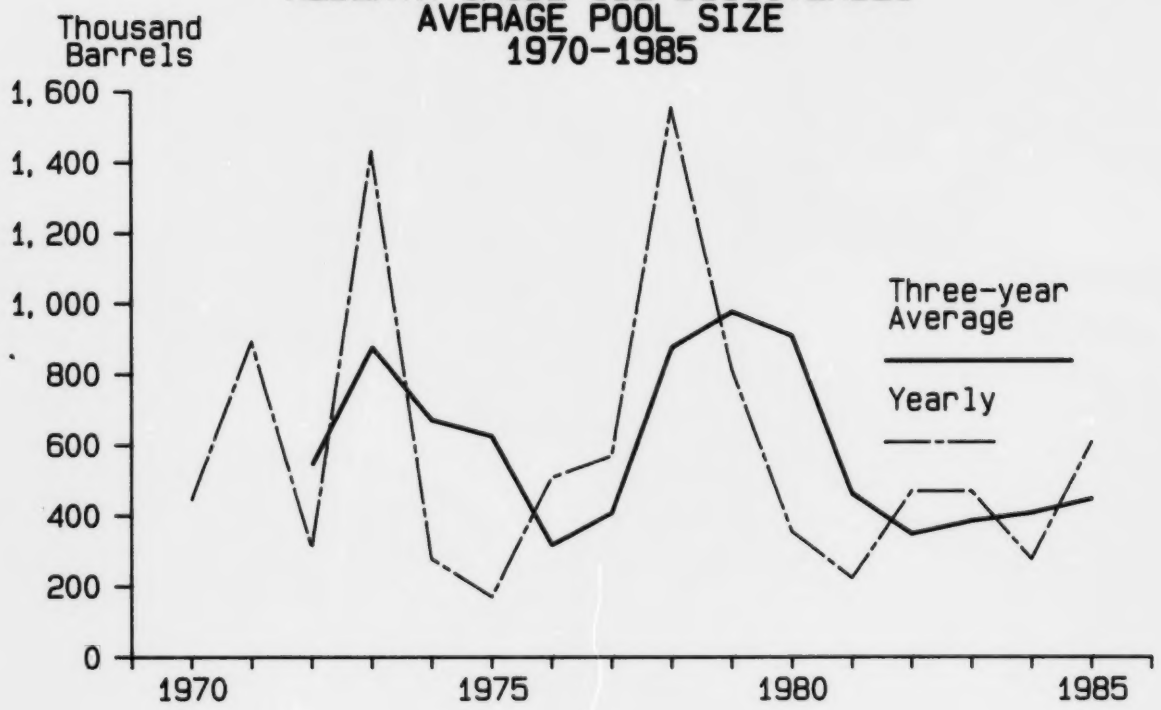
FIGURE 2.4
ALBERTA NATURAL GAS RESERVE ADDITIONS
PER FOOT DRILLED
1970-1985



SOURCE: Table A.7.

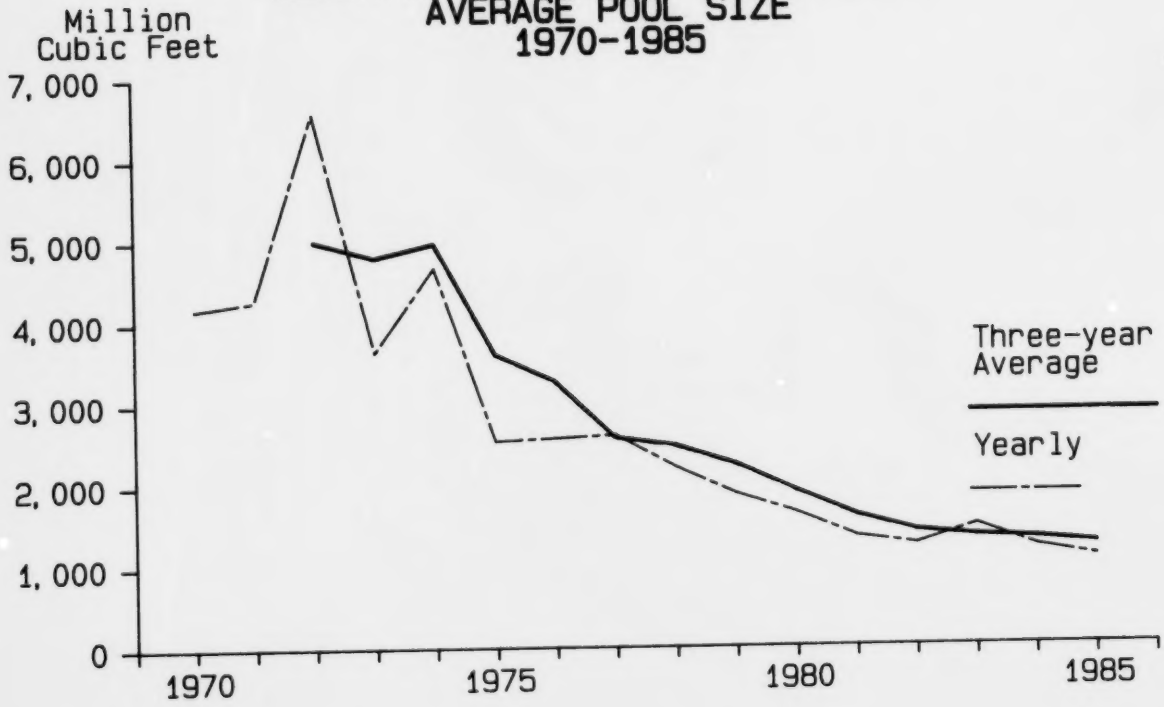
Note: Three-year moving averages.

FIGURE 2.5
ALBERTA CRUDE OIL DISCOVERIES
AVERAGE POOL SIZE
1970-1985



SOURCE: Alberta Energy Resources Conservation Board.

FIGURE 2.6
ALBERTA NATURAL GAS DISCOVERIES
AVERAGE POOL SIZE
1970-1985



SOURCE: Alberta Energy Resources Conservation Board.

are assumed to be fully appreciated (i.e., the 1985 estimates of the reserves discovered in those years are assumed to include the initial discovery and all reserves appreciation). The appreciation rates applied to the most recent estimates (as of December 31, 1985) of crude oil and raw natural gas reserves are shown in Table 2.2.

TABLE 2.2

ALBERTA CRUDE OIL AND RAW NATURAL GAS RESERVES
APPRECIATION RATES

	Years after Discovery					
	5	4	3	2	1	0
Crude Oil	1.0	1.7	2.1	2.3	2.5	2.7
Raw Natural Gas	1.0	1.8	2.4	2.9	3.0	3.4
Applied to data in year	1980	1981	1982	1983	1984	1985

2.2.3 Crude Oil Equivalence

Since exploration expenditures are not divided between crude oil and natural gas, the base case provides crude oil equivalent finding costs. This requires that natural gas reserves be converted to crude oil reserve equivalents. An historical (1970 to 1985) price equivalence of 9.4 thousand cubic feet of natural gas to one barrel of crude oil is used in the base case since price is the most relevant point of comparison in a commodity market (see Table A.9). Three sensitivity cases are also examined in which natural gas reserves are added on the basis of an energy equivalence of 6 thousand cubic feet to one barrel of crude oil; on the basis of a somewhat arbitrary netback equivalence of 18 thousand cubic feet to one barrel of crude oil; and on the basis of yearly price equivalence ratios.

Natural gas liquids reserves have been implicitly included in the analysis by employing raw natural gas reserves as opposed to marketable natural gas reserves. Sulphur reserves are included in the analysis to the extent that they constitute a part of raw natural gas reserves.

2.2.4 Exploratory Intent

Since exploration expenditures are available in aggregate form only, calculating separate crude oil and natural gas finding costs requires some measure of exploratory intent to estimate the share of total expenditures attributable to each hydrocarbon. One possible method of separating crude oil and natural gas finding costs is based on the assumption that if crude oil is found, crude oil was sought. The ratio of successful exploratory crude oil footage drilled to total successful exploratory footage drilled is a measure of crude oil intent.[3] Note that this procedure assumes that the same ratio applies to drilled and abandoned footage as well. This percentage is then applied to total exploration expenditures to calculate crude oil exploration expenditures. The residual is attributed to natural gas exploration. These expenditures are divided by the corresponding reserves found to determine separate crude oil and natural gas finding costs.

Results using this methodology are presented as an extension to the base case analysis. In order to account for the greater risks inherent in crude oil exploration relative to natural gas and for the fact that natural gas is often discovered while exploring for crude oil, separate finding costs are also calculated with crude oil intent increased by an arbitrary 25 percent at the expense of natural gas intent (see Table A.10).

2.2.5 Finding Costs with Time-Lagged Expenditures

In the base case analysis, the exploration expenditures of a given year are assigned to the reserves discovered in the same year. However, the exploratory process typically transpires over more than one year. The possible effects of the timing of expenditures are examined in an extension to the base case analysis. In the extension, land expenditures are lagged by two years and geological and geophysical expenditures are lagged by one year. Drilling expenditures in any given year are added to the two lagged expenditures and divided by the reserves discovered in that year according to the following formula:

$$FC_t = \left[LC_{t-2} \times \left(1 + r_{t-2} \right)^2 + GG_{t-1} \times \left(1 + r_{t-1} \right) + DR_t \right] / ARES_t$$

where: FC_t = finding costs at time period t
LC = land and rental costs
GG = geological and geophysical costs
DR = exploration drilling costs
ARES = fully appreciated reserves
r = the cost of money (see Table A.11)

It should be noted that these particular time lags are for representative purposes only as the actual timing of exploration varies considerably among plays.

2.3 Limitations of the Results

Several important limitations must be noted in interpreting the results of this report. First, the results provide aggregate finding cost estimates for hydrocarbon exploration by the entire industry in one province. The results are, therefore, a general guideline of industry finding costs in Alberta and are useful for comparative purposes with individual company finding costs. Although the results are reported in dollars and cents, general levels rather than precise figures should be examined. The overall trend in finding costs over time is the more significant result.

The second limitation to the results is that they must be examined strictly within the confines of the methodology and assumptions used in their calculation. Comparisons with finding cost estimates from other sources should be made only if the assumptions and methodologies used are comparable.

The finding cost estimates presented in this report are point-in-time estimates in that the reserves estimates that will be published in 1987 will differ from the 1986 published estimates used in this report. This is particularly applicable to the most recent years, especially in light of the recent decline in crude oil prices which may result in downward revisions in the reserves estimates of some years.

Finally, it should be noted that the purpose of this report is to provide estimates of Alberta hydrocarbon finding costs from 1970 to 1985 and to indicate the trend in finding costs over that time period. The reasons behind the changes or the trend in finding costs are not examined.

2.4 Comparison of Results with Earlier Report

The results presented in this report are not strictly comparable with those presented in CERI Research Report 85-2, Estimated Petroleum Finding Costs in Alberta: 1970-1983, due to differences in the methodologies used. In the earlier report, initial reserves discovered in each year were appreciated by an overall average appreciation rate calculated from reserves data for all years in the period under analysis. In the current report, the latest reserves estimate by year of discovery is appreciated, and then only for the last 5 years. Both methodologies are valid. However, while basically the same data were used in both reports, the differences in methodology yield different finding cost estimates. It should also be noted that the earlier results were in constant 1983 dollars while the current results are in constant 1985 dollars.

The methodology used to calculate finding costs in this report is presented simply as that, not as the only possible method of calculating finding costs. Although the same general trend is evident in the finding cost estimates of both the previous and the current report, the yearly estimates are more accurate under the current methodology in that the most recent, fully appreciated reserves estimates are used for each year rather than applying one general appreciation rate to the initial reserves estimate of every year. Further refinements in the methodology will be made in subsequent publications to improve the results wherever possible.

Footnotes

[1]Initial established crude oil and raw natural gas reserves are defined by the CPA as follows.

> Established Reserves: Those reserves recoverable under current technology and present and anticipated economic conditions, specifically proved by drilling, testing, or production, plus that judgement portion of contiguous recoverable reserves that are interpreted to exist, from geological, geophysical, or similar information, with reasonable certainty.
>
> Initial Established Reserves: Established reserves prior to the deduction of any production.
>
> Crude Oil: A mixture, consisting mainly of pentanes and heavier hydrocarbons that may contain sulphur compounds, that is liquid at the conditions under which its volume is measured or estimated, but excluding such liquids obtained from the processing of natural gas.
>
> Raw Natural Gas: The lighter hydrocarbons and associated non-hydrocarbon substances occurring naturally in an underground reservoir, which under atmospheric conditions is essentially a gas, but which may contain liquids.

[2]This methodology for calculating reserves appreciation was developed by J. R. Arrington (see J. R. Arrington, "Predicting the Size of Discoveries is Key to Evaluating Exploration Programs," Oil and Gas Journal, February 29, 1960, pp. 130-135). The application of Arrington's methodology is discussed by R. E. Megill in "How to Measure Exploration Profits" in the March 18, 1968 edition of Oil and Gas Journal, pp. 126-136.

[3]Exploratory footage includes footage from the five classes of exploratory wells categorized by the CPA: new field wildcat, new pool wildcat, deeper pool test, shallower pool test, and outposts. Exploratory footage is generally distinguished from development footage by the level of risk involved. See Canadian Petroleum Association, CPA Statistical Handbook (Calgary: Canadian Petroleum Association, 1986), Section I, Table 5D. Suspended well footage was not included in total exploratory footage.

Chapter 3

CRUDE OIL EQUIVALENT FINDING COSTS

This chapter presents crude oil equivalent finding costs calculated on the basis of the definitions and assumptions described in the previous chapter. Six sensitivity cases are also presented in which key variables are altered to determine their effect on the base case finding cost results.

3.1 Base Case Finding Costs

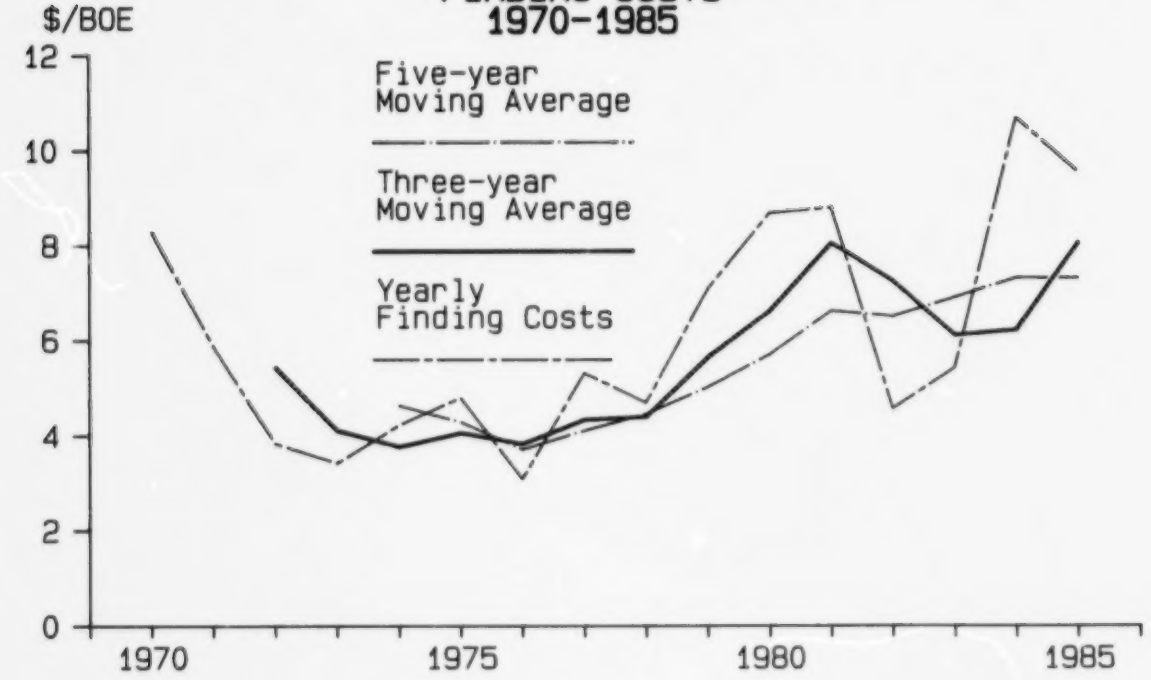
Base case finding costs are calculated as constant 1985 dollar exploration expenditures divided by fully appreciated crude oil equivalent reserves. Raw natural gas reserves are added on a price equivalence basis of 9.4 thousand cubic feet to one barrel of crude oil. The results are presented in Figure 3.1.

Three-year moving average base case finding costs generally fluctuate around $4 per barrel of oil equivalent until 1976. Two periods of increasing finding costs ensue, peaking at just over $8 per barrel of oil equivalent in both 1981 and 1985. The overall trend is evident in the 5-year moving averages which show a definite increase in finding costs from 1976 on.

Geological and geophysical expenditures account for about 20 percent of base case crude oil equivalent finding costs throughout the period (see Figure 3.2). Exploration drilling expenditures generally increase over the period such that their proportion of total finding costs increases from about 35 percent from 1970 to 1979 to about 50 percent thereafter. Land expenditures remain relatively constant over the period but decrease as a share of total finding costs to about 30 percent after 1979, from about 45 percent before that time.

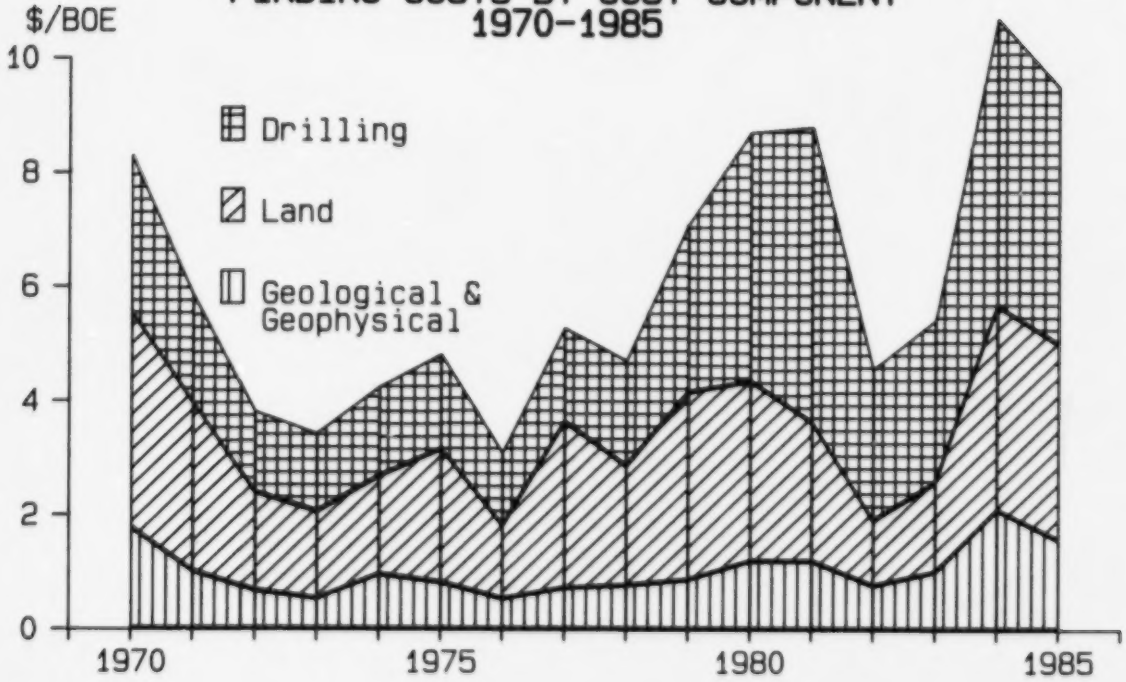
It is important to note that the increase in exploration drilling's share of total finding costs does not necessarily indicate either a change in emphasis on the part of explorationists or a change in activity levels. Relative changes in the price of geological and geophysical contracts, drilling contracts, and land also contribute to changes in the share of each cost component in total finding costs.

FIGURE 3.1
ALBERTA CRUDE OIL EQUIVALENT BASE CASE FINDING COSTS 1970-1985



SOURCE: Table B.1.

FIGURE 3.2
ALBERTA CRUDE OIL EQUIVALENT BASE CASE
FINDING COSTS BY COST COMPONENT
1970-1985



SOURCE: Table B.2.

3.2 Sensitivity Case Results

One of the principal assumptions made in calculating crude oil equivalent finding costs is the rate at which natural gas reserves are converted to crude oil equivalent reserves. In the base case, an historical price equivalence of 9.4 thousand cubic feet of natural gas to one barrel of crude oil is used. The first three sensitivities involve changes in this rate. In the other sensitivities, the appreciation rate is changed, only a portion of land expenditures is used, and an alternative data base for natural gas reserves is employed. The results are presented in Figures 3.3a and 3.3b.

3.2.1 Energy Equivalence Conversion

An alternative means for converting natural gas to crude oil equivalent is according to their relative energy content; 6 thousand cubic feet of natural gas to one barrel of crude oil. Three-year moving average crude oil equivalent finding costs calculated on this basis are about 30 percent lower than base case values. This difference decreases to about 20 percent in recent years as the proportion of natural gas reserves in total reserves decreases.

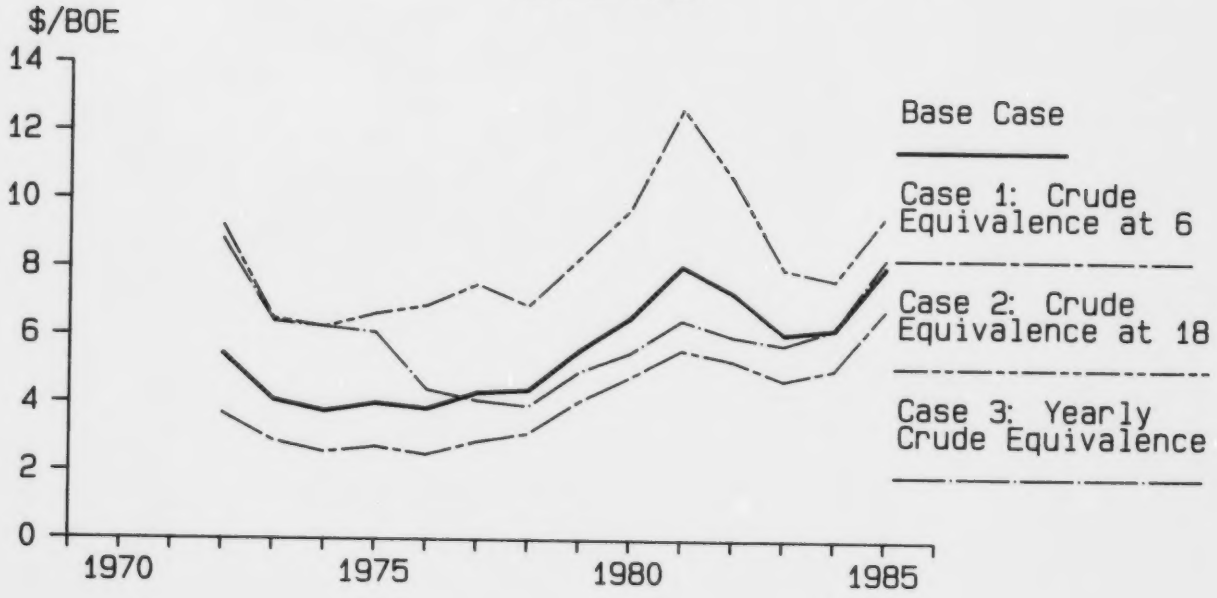
3.2.2 Approximate Netback Equivalence Conversion

Due to the greater uncertainty regarding the possibility of shut-in natural gas reserves relative to crude oil reserves, firms involved in the industry will sometimes discount substantially the value of natural gas reserves when estimating the value of crude oil equivalent reserves. An approximate netback equivalence of 18 thousand cubic feet of natural gas to one barrel of crude oil was arbitrarily selected to calculate crude oil equivalent finding costs in this sensitivity case. The results are about 55 to 70 percent higher than the base case results until 1982 but only about 25 percent higher thereafter as the proportion of natural gas reserves in total reserves decreases. The same trend as the base case is evidenced.

3.2.3 Crude Oil Equivalence at Yearly Rates

In the base case and each of the previous two sensitivity cases, one crude oil equivalence conversion rate is applied to all

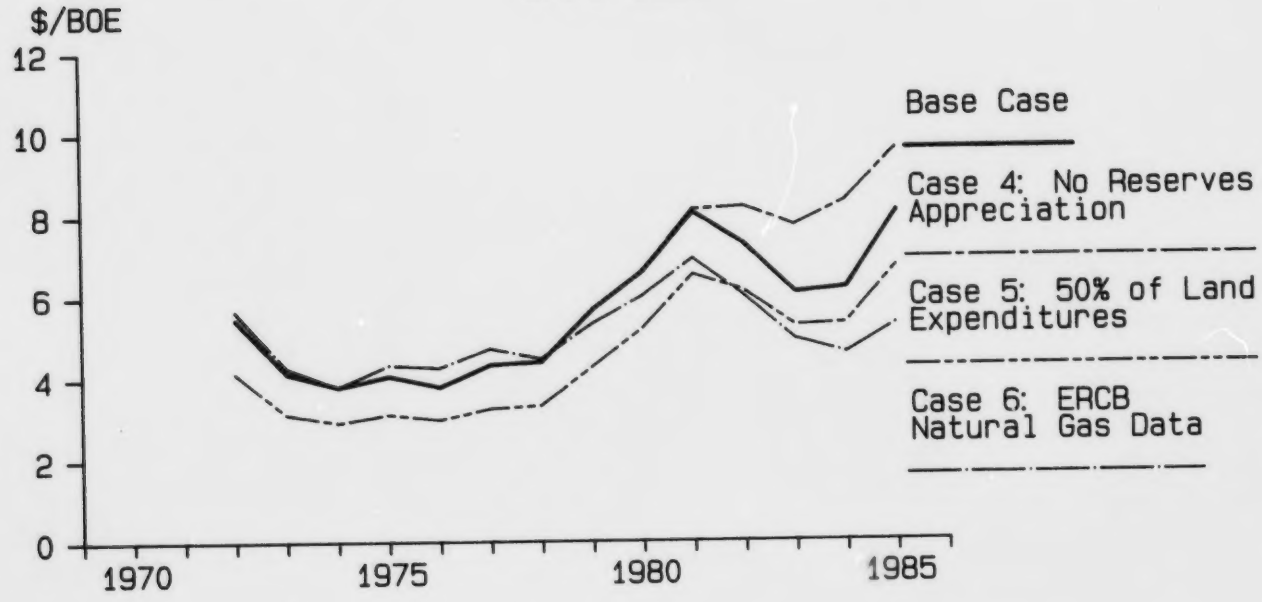
FIGURE 3.3a
ALBERTA CRUDE OIL EQUIVALENT
FINDING COST SENSITIVITY CASES (a)
1970-1985



SOURCES: Tables B.1 and B.3 to B.5.

(a) Three-year moving averages.

FIGURE 3.3b
ALBERTA CRUDE OIL EQUIVALENT FINDING COST SENSITIVITY CASES (a)
1970-1985



SOURCES: Tables B.1 and B.6 to B.8.

(a) Three-year moving averages.

years' data. The average price equivalence of 9.4 is calculated from yearly data which provide actual conversion rates varying between 19.3 and 6.5 over the period. Applying these yearly rates to the reserves data results in finding costs which are as much as 20 percent less than or 65 percent greater than base case finding costs. The largest differences occur in the early 1970s when the price ratio was much higher than on the average. Since both crude oil and natural gas prices were regulated for much of the period under analysis, the average rate for the entire period likely provides a better indication of the underlying trend.

3.2.4 No Reserves Appreciation

The amount of reserves appreciation is one of the most important and controversial assumptions to be made in calculating hydrocarbon finding costs. The argument has been made that recent reserves discoveries will not appreciate at all due to the relatively smaller pool sizes, the current poor economics of recovering new and some existing reserves, and the fact that reserves estimates themselves have become more accurate over time. It has also been suggested that the reserves estimates themselves are already overstated in that not all of these reserves could be economically produced (i.e., they are not truly recoverable). Applying appreciation rates to such figures is thought to be simply compounding the error.

This view is examined by calculating finding costs without any reserves appreciation (i.e., with reserves appreciation rates of 1.0). Only results from 1981 to 1985 vary as these are the only years in which a reserves appreciation rate greater than one is used in the base case. The 3-year moving average results are 12 to 34 percent higher than the base case results between 1982 and 1985.

3.2.5 Prorated Land and Rentals Expenditures

All land and rentals expenditures are included in calculating base case finding costs as part of total exploration expenditures. However, some portion of land expenditures in each year is likely attributable to development activities. Since this portion is unknown, finding costs are simply recalculated on the assumption that only 50 percent of land expenditures are related to exploration activities.[1] As a result, finding costs are 20 to 25 percent lower than base case finding costs. This difference decreases to about 15 percent after

1980 as the proportion of land expenditures in total expenditures declines.

3.2.6 Alternative Natural Gas Reserves Data

Canadian Petroleum Association crude oil and raw natural gas reserves data are used in the base case analysis. The reserves data employed are initial established reserves by year of discovery. The Alberta Energy Resources Conservation Board publishes hydrocarbon reserves data but not dated back to the year of discovery. However, ERCB Report ST 86-47, "Alberta Gas Reserve Trends," presents initial reserves of marketable natural gas by year of discovery and appreciation factors which are used to calculate fully appreciated natural gas reserves.[2] These data are employed in the final sensitivity analysis.

It should be noted that the finding cost results for this sensitivity case are not strictly comparable vis-a-vis the base case results in that pentanes plus and natural gas liquids reserves are included in the base case raw natural gas reserves estimates but not in the ERCB marketable natural gas reserves estimates. CPA crude oil reserves are used in both cases.

The 3-year moving average sensitivity case results generally track the base case results, on a higher level until 1978 and then on a lower level until 1980. The results are significantly below the base case beginning in 1981 due to higher reserves estimates and, for 1985, a higher reserves appreciation rate.[3]

3.3 Summary

Base case finding cost results vary both yearly and as 3-year moving averages but demonstrate an overall increasing trend in the 5-year moving averages. Exploration drilling expenditures account for a greater portion of total finding costs in recent years.

The sensitivity cases emphasize the importance of interpreting finding cost results in light of the underlying assumptions. Of all the sensitivities presented, changes in the crude oil equivalence conversion rate and in the reserves data base have the greatest impact on base case finding costs.

The next chapter discusses the extensions to the base case.

Footnotes

[1]Land bonus payment data for 1985 received from the Alberta Department of Energy indicate that this ratio between exploration and development is close to being accurate, at least for 1985. The generalization can be made that bonus payments for licenses are for exploration activity and bonus payments for leases are for development activity. Licenses accounted for 54 percent of total 1985 bonus payments which, in turn, accounted for almost 80 percent of total 1985 land and rentals expenditures in Alberta. Land retention costs, bonuses paid for acquisition of freeholders' mineral rights, land department salaries and overhead, land site acquisitions, and legal and filing fees account for the remaining land expenditures.

[2]Alberta Energy Resources Conservation Board, "Alberta Gas Reserve Trends," ERCB Report ST 86-47 (Calgary: Alberta Energy Resources Conservation Board, 1986), p. 17.

[3]For a discussion of the differences between CPA and ERCB hydrocarbon reserves data, see James N. Tanner, Reserves of Hydrocarbons in Alberta: A Review of Canadian Petroleum Association and Alberta Energy Resources Conservation Board Estimates and Methodology, CERI Research Report 86-2 (Calgary: Canadian Energy Research Institute, 1986).

Chapter 4

EXTENSIONS TO THE BASE CASE ANALYSIS

The usefulness of the base case finding costs can be increased in several ways, two of which are explored in this chapter. First, separate crude oil and natural gas finding costs are calculated as opposed to crude oil equivalent finding costs. Second, the timing of expenditures in the exploratory process is addressed by lagging appropriate expenditures.

4.1 Separate Crude Oil and Natural Gas Finding Costs

Separate crude oil and natural gas finding costs are calculated by applying a measure of exploratory intent to total exploration expenditures, as discussed in Chapter 2. Figure 4.1 presents estimated crude oil intent for the 1970 to 1985 period. Natural gas intent is equal to the residual (i.e., 1 - oil intent).

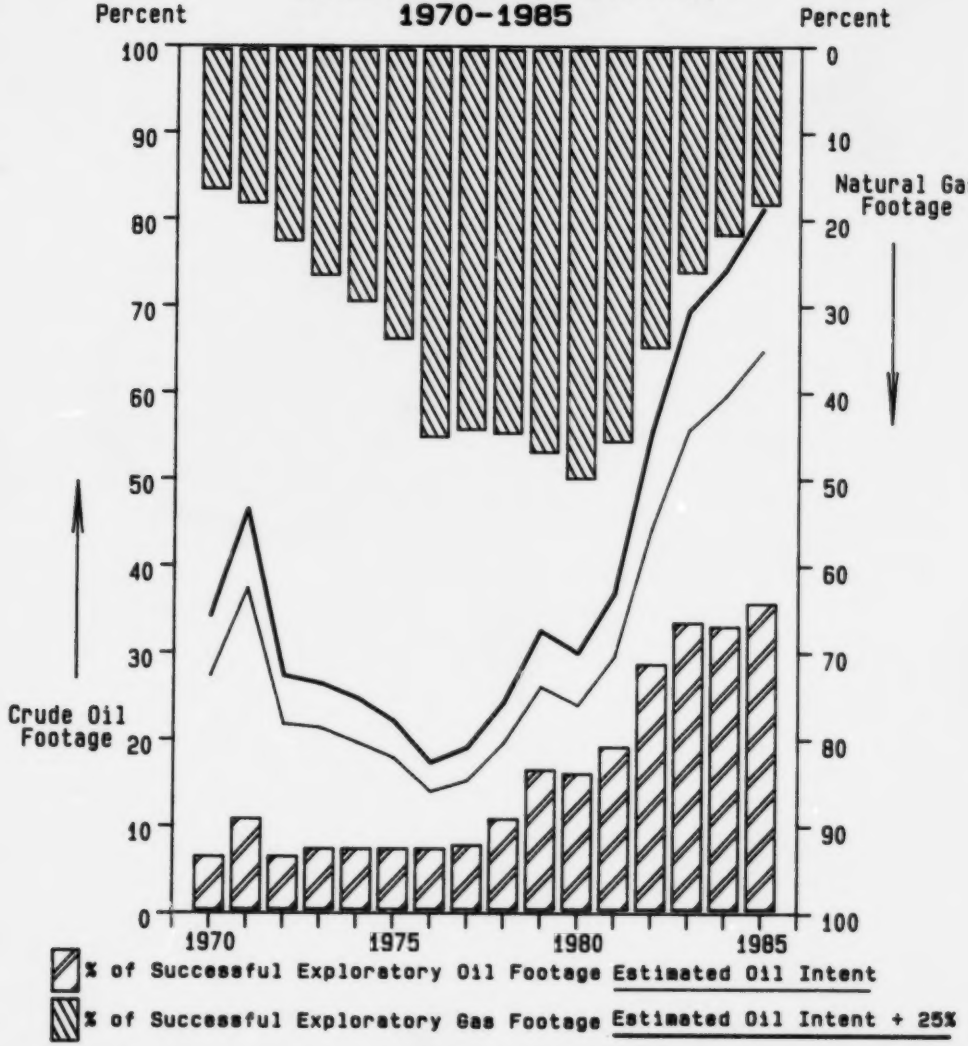
Three-year moving average crude oil finding costs fluctuate considerably over the period from a low of about $3 per barrel to a high of almost $11 per barrel (see Figure 4.2). The results peak in 1976 and 1981 but demonstrate a general increasing trend, reaching $7.40 in 1985. Increasing crude oil intent by 25 percent increases these values by about $1.20 per barrel.

Three-year moving average natural gas finding costs show a definite upward trend over the period, increasing from about $0.40 per thousand cubic feet to reach $1 per thousand cubic feet in 1985 (see Figure 4.3). Increasing crude oil intent by 25 percent has a greater negative impact on natural gas finding costs at the end of the period as oil intent is also increasing.

4.2 Finding Costs with Time-Lagged Expenditures

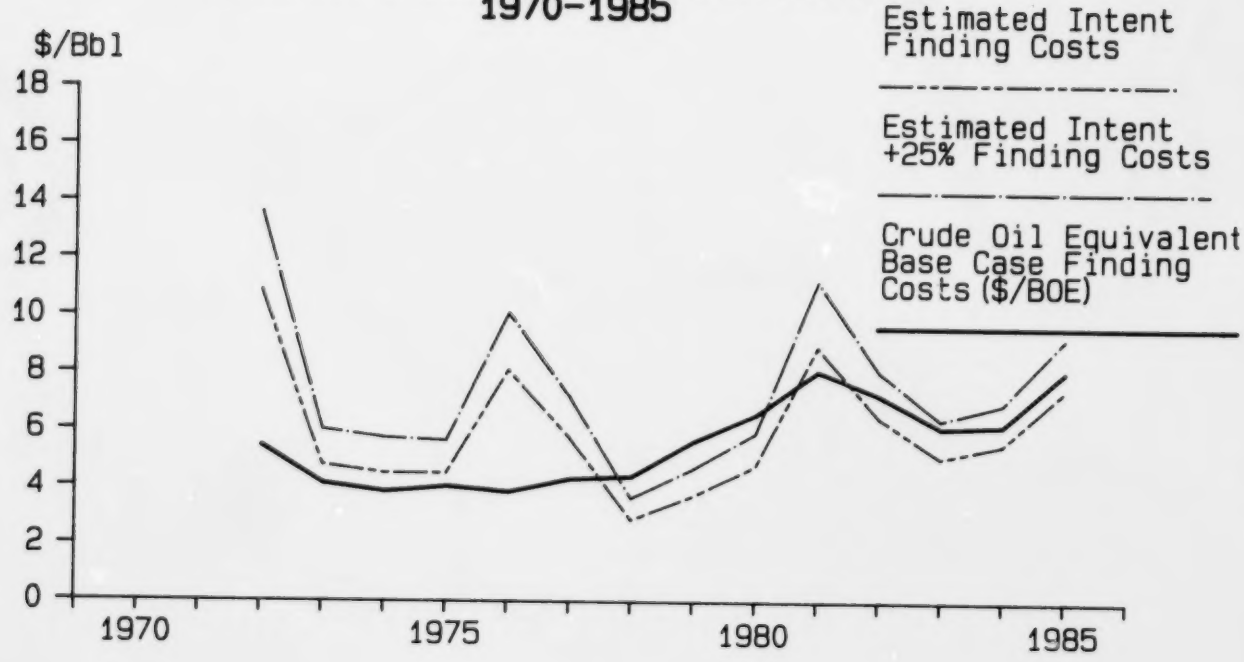
To account for the timing element involved in the exploratory process, finding costs are recalculated with land expenditures lagged by two years and geological and geophysical expenditures lagged by one

FIGURE 4.1
INTENT ESTIMATION FOR ALBERTA EXPLORATION ACTIVITY(a) 1970–1985



SOURCE: Table A.10.
(a) Three-year moving averages.

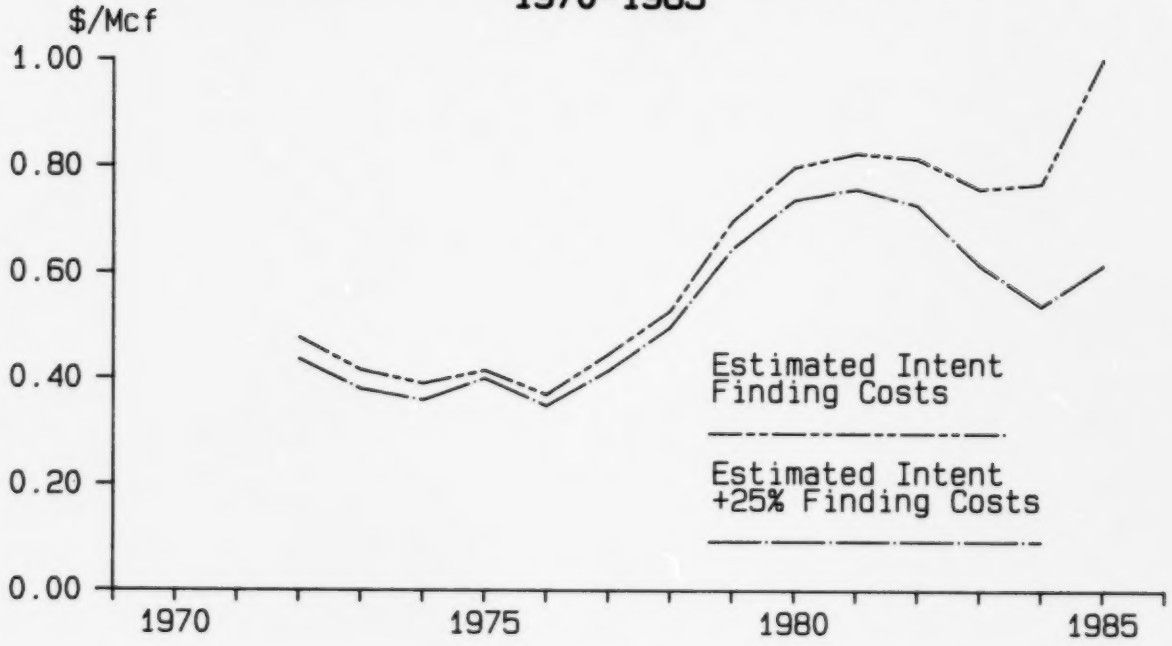
FIGURE 4.2
ALBERTA CRUDE OIL FINDING COSTS (a)
1970-1985



SOURCES: Tables B.1, C.1, and C.3.

(a) Three-year moving averages.

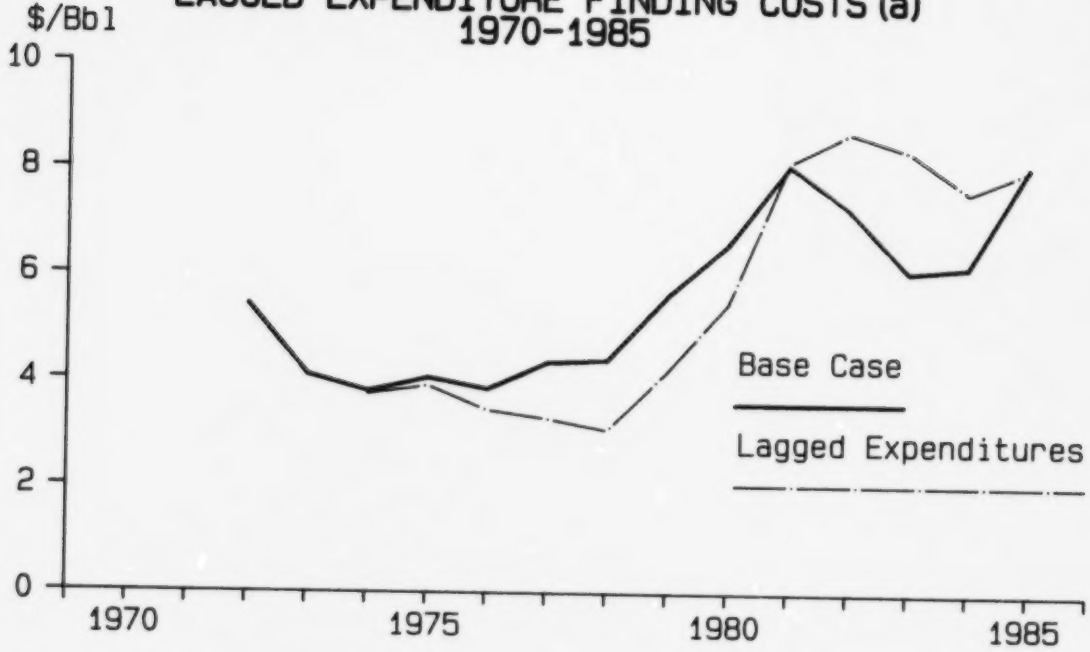
FIGURE 4.3
ALBERTA NATURAL GAS FINDING COSTS (a)
1970-1985



SOURCES: Tables B.1, C.2, and C.4.

(a) Three-year moving averages.

FIGURE 4.4
ALBERTA CRUDE OIL EQUIVALENT LAGGED EXPENDITURE FINDING COSTS (a) 1970-1985



SOURCES: Tables B.1 and C.5.

(a) Land expenditures lagged two years, and geological and geophysical expenditures lagged one year. Three-year moving averages.

year. The cost of money is included in the calculation as outlined in Chapter 2.

Lagged expenditure finding costs follow the same trend as base case finding costs on both a 3-year and a 5-year moving average basis (see Figure 4.4). The 3-year moving averages generally increase to 1982, decline, and then increase again to 1985. The 5-year moving averages show a clear upward trend (see Table C.5).

The relatively steady interest rates of the 1970s actually result in a reduction in finding costs over the base case despite the fact that the cost of money is added. However, the higher interest rates experienced in the 1980s produce finding costs considerably greater than the base case results.

Chapter 5

SUMMARY

The purpose of this report is to provide a methodology for calculating hydrocarbon finding costs and to present finding cost estimates based on this methodology for the Province of Alberta for the 1970 to 1985 period.

Finding cost is defined as the ratio of exploration expenditures in a given year to fully appreciated reserves discovered in that year. All results are presented in 1985 constant dollars.

Small pool reserves and reserves discovered before 1981 are assumed to be fully appreciated. Appreciation rates are applied to large pool reserves discovered from 1981 to 1985.

In the base case, natural gas reserves are converted to crude oil equivalent reserves using an historical price ratio of 9.4 thousand cubic feet of natural gas to one barrel of crude oil. Pentanes plus, natural gas liquids, and sulphur reserves are implicitly included in the analysis insofar as they constitute a portion of raw natural gas reserves.

5.1 Results

The base case results show a general upward trend in the 3-year moving averages that is emphasized in the 5-year moving averages. The 3-year moving averages peak in 1981, decline, and then increase again to 1985.

Six crude oil equivalent sensitivity cases are explored as follows:

(1) Energy equivalence conversion;
(2) Approximate netback equivalence conversion;
(3) Equivalence conversion at yearly rates;
(4) No reserves appreciation;
(5) 50 percent of land expenditures; and
(6) Alternative natural gas reserves data base.

Of all the sensitivity cases presented, changing the crude oil equivalence conversion rate and using an alternative natural gas reserves data base have the most significant impact on the base case results. Table 5.1 summarizes the base case and sensitivity case results.

Two extensions to the base case are also examined. First, a measure of exploratory intent based on successful footage drilled is used to disaggregate exploration expenditures and calculate separate crude oil and natural gas finding costs. Second, the timing of the exploration process is accounted for by lagging land expenditures by two years and geological and geophysical expenditures by one year. The results of both extension cases follow the same general trend as the base case results (see Table 5.2).

5.2 Preferred Case Finding Costs

The base case results presented in this report provide a starting point from which more accurate estimates of finding costs can be made. The sensitivity and extension cases indicate how the base case results are affected either by making changes in the fundamental assumptions or by attempting to more accurately account for the actual exploration process. However, the question remains as to what combination of methodology and assumptions provides the best estimates of Alberta hydrocarbon finding costs. The following discussion outlines such a preferred case and provides finding cost results for this case. The intent here is not to calculate finding cost estimates that are "right" at the exclusion of all other estimates. Such a task is clearly impossible with imprecise methodologies using imperfect data. The intent is, rather, to provide estimates of finding costs which incorporate the methodology and assumptions which are considered to be the most appropriate.

Preferred case finding cost estimates are provided separately for both crude oil and natural gas as these are the actual targets of exploration activity. Crude oil intent is increased by 25 percent to account for the greater risk associated with crude oil exploration and for the fact that natural gas is often discovered as a result of crude oil exploration.

As discussed in Chapter 2, some unknown portion of total land expenditures is actually attributable to exploration with the residual being the result of development activity. Low and high preferred cases are created by using 50 percent of land expenditures and 100 percent of

TABLE 5.1

SUMMARY OF CRUDE OIL EQUIVALENT FINDING COST RESULTS
1970-1985
($1985 per BOE; 3-year moving averages)

Year	Base Case	Energy Equivalence Conversion[a]	Approximate Netback Equivalence Conversion[b]	Equivalence Conversion at Yearly Rates[c]	No Reserves Appreciation	50 Percent of Land Expenditures	Alternative Natural Gas Reserves Data Base[d]
1970	NA	NA	NA	NA	NA	NA	NA
1971	NA	NA	NA	NA	NA	NA	NA
1972	5.50	3.70	9.30	8.80	5.50	4.20	5.70
1973	4.20	2.90	6.60	6.50	4.20	3.20	4.30
1974	3.80	2.60	6.30	6.30	3.80	3.00	3.90
1975	4.10	2.80	6.70	6.10	4.10	3.20	4.40
1976	3.90	2.50	6.90	4.50	3.90	3.00	4.30
1977	4.40	2.90	7.60	4.10	4.40	3.30	4.80
1978	4.50	3.10	6.90	4.00	4.50	3.40	4.50
1979	5.70	4.10	8.40	5.00	5.70	4.30	5.40
1980	6.60	4.80	9.80	5.60	6.60	5.20	6.10
1981	8.10	5.70	12.80	6.50	8.20	6.60	7.00
1982	7.30	5.30	10.70	6.10	8.20	6.20	6.10
1983	6.10	4.80	8.10	5.80	7.80	5.30	5.00
1984	6.30	5.10	7.70	6.30	8.40	5.30	4.70
1985	8.10	6.80	9.70	8.30	9.60	6.80	5.40

SOURCE: Tables B.1 to B.8.

[a]Six thousand cubic feet of natural gas to one barrel of crude oil.
[b]Eighteen thousand cubic feet of natural gas to one barrel of crude oil.
[c]Based on wellhead price ratios.
[d]Based on Alberta Energy Resources Conservation Board data.

TABLE 5.2

SUMMARY OF FINDING COST RESULTS
1970–1985
($1985; 3-year moving averages)

	Base Case ($/BOE)	Crude Oil[a] ($/bbl)	Natural Gas[a] ($/Mcf)	Lagged Expenditures[b] ($/BOE)
1970	NA	NA	NA	NA
1971	NA	NA	NA	NA
1972	5.50	10.90	0.50	NA
1973	4.20	4.80	0.40	NA
1974	3.80	4.60	0.40	3.80
1975	4.10	4.50	0.40	3.90
1976	3.90	8.10	0.40	3.50
1977	4.40	5.80	0.50	3.30
1978	4.50	2.90	0.50	3.10
1979	5.70	3.70	0.70	4.20
1980	6.60	4.80	0.80	5.50
1981	8.10	9.00	0.80	8.20
1982	7.30	6.50	0.80	8.70
1983	6.10	5.10	0.80	8.40
1984	6.30	5.60	0.80	7.60
1985	8.10	7.40	1.00	8.10

SOURCE: Tables C.1 to C.5.

[a]Based on crude oil intent.
[b]Land expenditures and geological and geophysical expenditures lagged by two years and one year, respectively.

land expenditures, respectively. Actual preferred case finding costs lie within the range specified by these two cases.

Preferred case finding cost results are presented in Figures 5.1 and 5.2 for crude oil and natural gas, respectively. Finding costs for both hydrocarbons demonstrate a general upward trend over the period. This is particularly evident for natural gas. Three-year moving average preferred case crude oil finding costs range from about $8 to $9 per barrel in 1985. Natural gas results at the end of the period are in the range of 50 cents to 60 cents per thousand cubic feet.

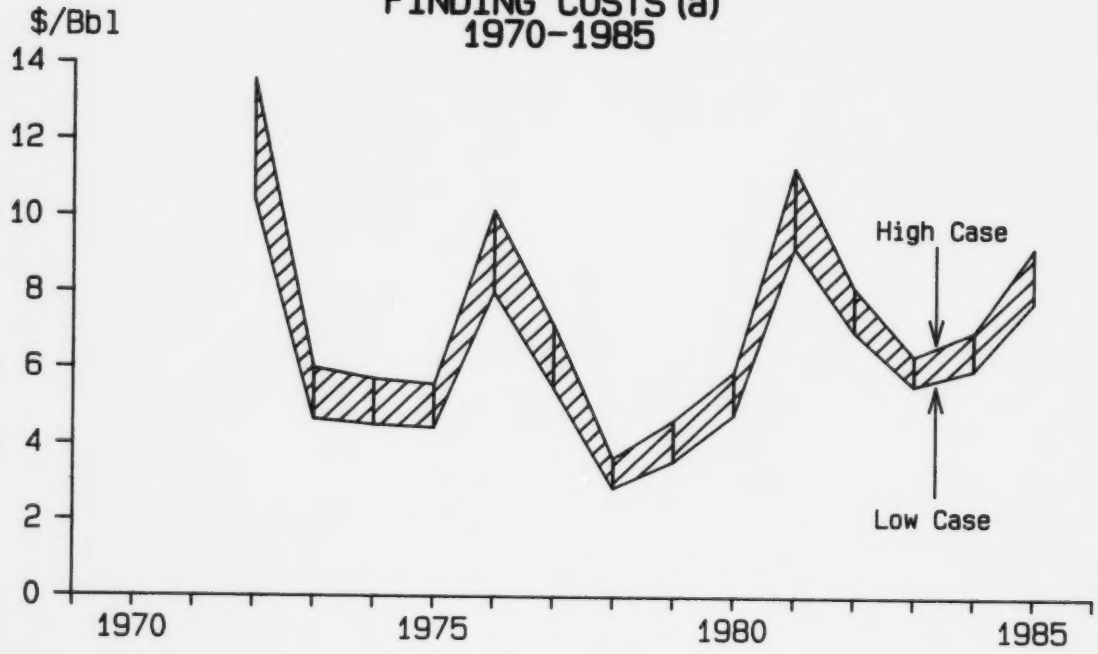
To increase the accuracy of the results, land expenditures and geological and geophysical expenditures should be lagged to account for the time element involved in the exploratory process. However, since the actual timing of these expenditures varies significantly among plays as well as over time, it is not clear that assigning arbitrary lags actually improves the degree of accuracy in the estimates. Incorporating the same lag used in the extension case (land expenditures lagged by two years and geological and geophysical expenditures lagged by one year) changes the preferred case results somewhat without altering the general trend (see Tables D.5 to D.8).

5.3 Trends in Alberta Hydrocarbon Finding Costs

All of the finding cost results presented in this report, including the base case, sensitivity cases, extension cases, and preferred cases, demonstrate the same general upward trend over the 1970 to 1985 period. This conclusion is not surprising given the corresponding downward trends both in reserve additions per foot drilled and in the average pool size of new discoveries. The question remains, however, as to whether this trend in finding costs can be expected to continue in the future. While the purpose of this report is not to forecast finding costs, some general observations can be made regarding the level of finding costs that could be expected for 1986 under certain assumptions.

Oil and gas industry license and lease bonus payments in Alberta to the end of November 1986 are only 31 percent of year ago levels: about $231 million in 1986 versus $742 million in 1985.[1] Geophysical activity in Alberta for the first 11 months of 1986 is only about 60 percent of 1985 levels.[2] The total 1986 expenditures

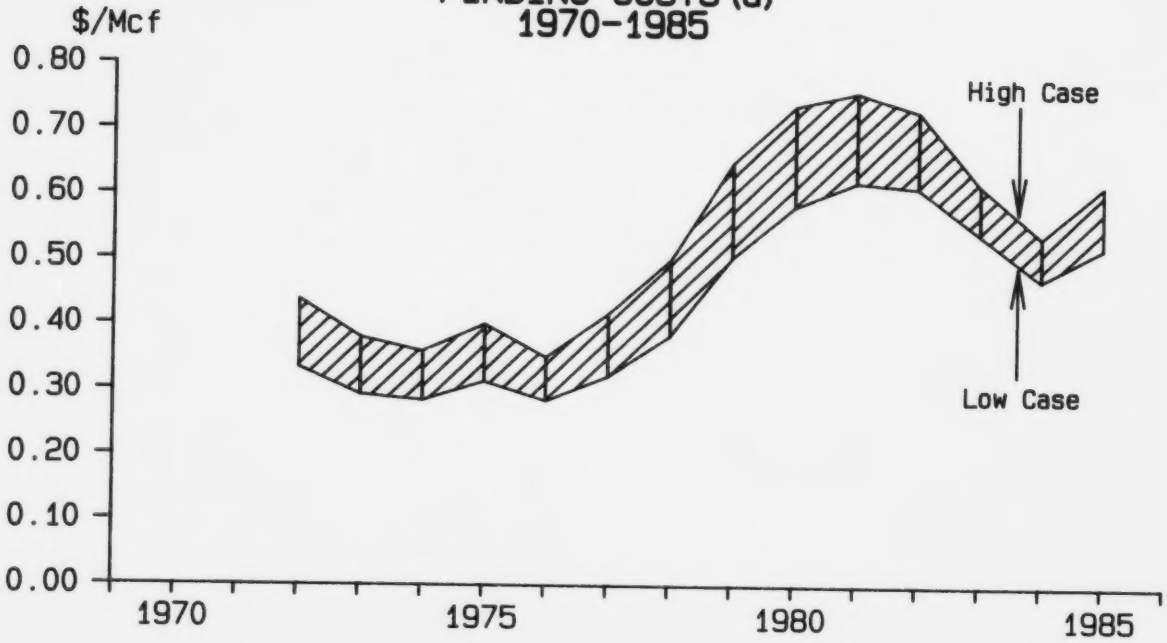
FIGURE 5.1
ALBERTA PREFERRED CASE CRUDE OIL FINDING COSTS (a) 1970-1985



SOURCES: Tables D.1 and D.2.

(a) Three-year moving averages. Low case and high case based on 50% and 100% of land expenditures, respectively.

FIGURE 5.2
ALBERTA PREFERRED CASE NATURAL GAS
FINDING COSTS (a)
1970-1985



SOURCES: Tables D.3 and D.4.

(a) Three-year moving averages. Low Case and High Case based on 50% and 100% of land expenditures, respectively.

derived by multiplying the above percentages by total 1985 expenditures closely parallel expected 1986 expenditures obtained from a June 1986 survey of oil and gas operators.[3]

Drilling activity in Alberta is down about 40 percent in 1986 from 1985 levels. Total wells and total exploratory footage drilled in Alberta to the end of the first week in December have decreased 31 percent and 27 percent, respectively, from 1985 levels.[4] The cumulative average number of rigs drilling in Canada is down 41 percent to the end of the first week of December.[5] In addition, the results of a mid-1986 survey of drilling rig and other service and supply contractors indicated that market prices for drilling rig contract services were as much as 50 percent below year-ago levels.[6] Drilling-related service firms indicated similar price declines. These lower prices suggest that total exploratory drilling expenditures will likely fall by more than the 30 percent decline in activity noted to date from 1985 levels. The same is likely true for total geological and geophysical expenditures.[7]

In light of the above, total exploration expenditures in Alberta in 1986 could be only about 60 percent of total 1985 exploration expenditures. Since drilling activity is only down about 30 percent from 1985 levels, 1986 finding costs will be lower than in 1985 provided that success rates and reserve addition rates remain constant. However, this downward pressure on Alberta finding costs may be offset by the declining average pool size of discoveries and declining reserve additions per foot drilled noted above, and by the fact that the proportion of successful wells drilled is down somewhat from 1985.[8] In addition, it should be noted that if crude oil prices remain at current levels (about $16 to $18 U.S. per barrel for West Texas Intermediate at Chicago, December 1986), then some of the small pool reserves that have been and will be found may not be economic. This fact in itself may result in an increase in finding costs in 1986 since estimates of recoverable reserves are dependent on economic as well as technical considerations. Moreover, if the estimated share of recent reserves discoveries that is actually recoverable is high in light of the current economic situation, then the finding cost estimates derived for these years are low. This would emphasize the increasing trend evident in the finding costs results. Given the lower level of crude oil prices, this trend is reason for concern on the part of both industry and governments.

5.4 Qualifications and Areas for Further Analysis

It is of vital importance that the finding cost estimates presented in this report are interpreted in the context of the definitions used and the assumptions made. The results are industry averages for the Province of Alberta and are intended as simply a point of reference against which individual firms can compare their own finding costs. Even then, comparisons are valid only if the same methodology is used.

Although the estimates are presented in dollars and cents, distinctions should not be made to that level of precision. The overall trend is the most significant result to be derived from any given series.

The usefulness of provincial averages is limited in that finding costs vary significantly among regions within the Province of Alberta. Finding cost results for even general regions within the province would be more interesting and easier to apply. Full-cycle costs, including finding, development, and production costs, would also be more useful.

Footnotes

[1]Personal correspondence, Alberta Department of Energy, Resource Agreements Branch.

[2]A total of 56 265 kilometres of seismic line were shot in Alberta in the first 9 months of 1986 compared with 97 439 kilometres shot in the same period in 1985 (personal communication, Canadian Association of Geophysical Contractors, December 1986). In addition, the average geophysical crew count for Canada is expected to be 53 for 1986 versus 84 in 1985. See Oilweek, December 15, 1986, p. 13.

[3]The survey results indicated total expected Alberta geological and geophysical expenditures of $355 million in 1986 and total expected Alberta land expenditures of $356 million in 1986. In comparison, 60 percent of 1985 Alberta geological and geophysical expenditures results in $288 million in 1986, and 31 percent of 1985 Alberta land expenditures results in $317 million in 1986. See Janice L. Pasay, Louise Gill, and Walter W. Haessel, The Impact of Lower Oil and Gas Prices on the Oil and Gas Industry in Alberta (Calgary: CERI Energy Research Ltd., 1986).

[4]Oilweek, December 15, 1986, p. 1.

[5]Ibid., p. 1.

[6]Janice L. Pasay, Louise Gill, and Walter W. Haessel, The Impact of Lower Oil and Gas Prices on the Oil and Gas Industry in Alberta, pp. 37-38.

[7]Geophysical contractors interviewed in June 1986 also indicated that then-current prices for their services were as much as 50 percent lower than year-ago levels. See ibid, p. 37.

[8]At the end of the first week of December 1986, 1,128 or 25 percent of the 4,528 wells drilled in Alberta were dry. In the same period in 1985, 1,476 wells or 22 percent of the total of 6,571 wells drilled were dry. See Oilweek, December 15, 1986, p. 1.

APPENDIX A

BACKGROUND DATA

TABLE A.1

ALBERTA
NET CASH EXPENDITURES
1970 - 1985
(MILLIONS OF CURRENT DOLLARS)

YEAR	EXPLORATION				DEVELOPMENT	EXPLORATION AND DEVELOPMENT
	GEOLOGICAL AND GEOPHYSICAL	DRILLING	LAND PURCHASE AND RENTALS	TOTAL EXPLORATION		
1970	80.3	83.8	116.6	280.7	327.7	608.4
1971	65.5	80.8	125.9	272.2	376.1	648.3
1972	71.2	102.1	124.4	297.7	333.0	630.7
1973	78.7	131.4	144.3	346.4	350.7	697.1
1974	112.4	146.5	157.3	416.2	455.4	871.6
1975	99.0	149.1	207.9	456.0	562.0	1018.0
1976	145.5	256.5	255.5	657.5	845.6	1503.1
1977	223.4	394.7	679.9	1298.0	861.2	2159.2
1978	358.3	644.5	748.5	1735.3	1129.2	2864.5
1979	349.7	1027.5	1144.7	2521.9	1538.3	4060.2
1980	452.3	1621.6	1176.5	3250.4	2340.7	5591.1
1981	352.2	1543.7	721.3	2617.2	2418.3	5035.5
1982	325.1	1076.3	465.6	1867.0	2408.2	4275.2
1983	372.7	1017.4	565.1	1955.2	1801.4	3756.6
1984	472.3	1138.3	798.2	2392.8	2136.0	4528.8
1985	488.5	1368.3	1021.1	2869.9	2879.9	5749.8

SOURCE: Canadian Petroleum Association, CPA Statistical Handbook, as updated to 1986 (Calgary: Canadian Petroleum Association, 1986), Section IV, Tables 3B-3C.

TABLE A.2

CPA COST ESCALATION INDICES
BY EXPENDITURE TYPE
1970 - 1985
(1985 = 100)

YEAR	GEOLOGICAL AND GEOPHYSICAL COSTS	EXPLORATION AND DEVELOPMENT DRILLING	EOR AND FIELD EQUIPMENT	GAS PLANT CONSTRUCTION COSTS	TOTAL CONSTRUCTION COSTS
1970	27.9	19.2	28.6	14.5	19.0
1971	29.9	19.8	22.0	16.4	20.5
1972	31.6	22.1	24.5	18.1	22.6
1973	33.8	25.4	29.2	20.1	25.9
1974	37.4	30.2	37.0	23.0	31.0
1975	46.4	35.6	43.8	27.2	36.7
1976	52.0	40.6	49.4	37.8	43.2
1977	57.3	44.6	55.3	48.6	47.7
1978	66.5	52.1	59.7	59.1	54.2
1979	72.1	62.7	66.9	66.2	62.9
1980	78.8	77.9	73.5	72.9	74.5
1981	84.4	86.2	82.7	82.3	83.5
1982	89.9	89.8	89.7	89.9	89.9
1983	91.6	91.5	91.6	91.6	91.6
1984	95.3	95.2	95.3	95.2	95.2
1985	100.0	100.0	100.0	100.0	100.0

SOURCES: (1) Canadian Petroleum Association, "Capital Cost Escalation Study Update" (Calgary: Canadian Petroleum Association, 1984) (Mimeod); and (2) Personal communication with the Canadian Petroleum Association.

TABLE A.3

ALBERTA
NET CASH EXPENDITURES
1970 - 1985
(MILLIONS OF 1985 CONSTANT DOLLARS)

YEAR	EXPLORATION				DEVELOPMENT(b)	EXPLORATION AND DEVELOPMENT
	GEOLOGICAL AND GEOPHYSICAL	DRILLING	LAND PURCHASE AND RENTALS(a)	TOTAL EXPLORATION		
1970	287.8	436.5	607.3	1331.6	1952.2	3283.7
1971	219.1	488.1	635.9	1263.0	2073.6	3336.6
1972	225.3	462.0	562.9	1250.2	1552.8	2803.0
1973	289.2	517.3	568.1	1294.6	1362.7	2657.3
1974	388.5	485.1	528.9	1386.5	1529.9	2836.4
1975	213.4	418.8	584.0	1216.2	1578.3	2794.5
1976	279.8	631.8	629.3	1540.9	1936.7	3477.5
1977	389.9	885.0	1524.4	2799.3	1756.8	4556.1
1978	526.8	1237.0	1421.3	3185.1	2019.3	5204.4
1979	485.0	1638.0	1825.7	3949.5	2380.1	6329.6
1980	574.0	2081.6	1510.3	4165.9	3101.7	7267.6
1981	417.3	1798.0	836.8	3044.9	2871.7	5916.6
1982	361.6	1198.6	518.5	2078.7	2682.3	4761.0
1983	486.9	1111.9	617.6	2136.4	1967.7	4104.1
1984	495.6	1187.3	830.0	2512.9	2242.7	4755.7
1985	488.5	1368.3	1021.1	2869.9	2879.9	5749.8

SOURCE: Tables A.1 and A.2.

(a) As recommended by the Canadian Petroleum Association, land expenditures were converted to constant dollars using the drilling cost index.
(b) The components of total development expenditures were converted to constant dollars and then aggregated to derive total constant dollar development expenditures.

TABLE A.4

ALBERTA CRUDE OIL RESERVES APPRECIATION (a)
1970-1985
(1946 #43)

Year of Discovery	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1970	6.6	7.6	7.8	6.5	6.5	6.5	6.4	6.3	6.9	7.6	7.5	7.5	8.0	8.1	4.5	3.6
1971	3.1	4.3	5.0	6.7	6.6	6.5	6.2	6.4	5.9	6.9	6.6	5.3	6.2	6.4	9.5	
1972	1.3	1.8	2.8	2.5	2.5	5.0	5.5	5.1	5.1	5.3	5.5	5.6	3.2	3.2		
1973	1.8	1.8	5.1	7.8	6.3	5.8	6.3	5.8	5.9	5.8	6.3	15.0	21.0			
1974	0.8	1.2	1.7	2.3	2.6	3.0	3.3	3.8	4.0	3.8	3.9	4.0				
1975	0.3	1.1	1.0	1.2	1.3	1.2	1.2	1.6	1.5	1.2	1.6					
1976	0.2	0.8	2.0	16.9	17.1	5.3	6.2	6.5	7.9	8.0						
1977	16.0	28.0	28.0	31.6	7.7	9.3	11.4	13.3	14.3							
1978	8.0	7.1	8.6	28.4	29.6	31.9	29.5	46.8								
1979	4.9	8.1	15.4	15.0	18.4	25.0	27.8									
1980	5.9	8.5	3.5	3.8	13.2	14.3										
1981	5.5	8.4	16.0	8.1	5.0											
1982	7.8	18.1	25.2	25.4												
1983	4.2	24.2	23.4													
1984	25.0	13.6														
1985	48.2															
Sum of Colum	121.4	128.6	142.1	157.2	128.8	113.8	113.8	95.6	51.5	38.6	33.4	45.4	48.4	19.7	14.0	3.6
Sum of Previous Colum(b)		81.2	107.0	118.7	130.8	111.8	99.5	86.0	48.8	37.2	28.6	31.8	41.4	19.4	16.5	4.5
Appreciation Factor(c)		1.49	1.33	1.32	0.92	1.02	1.14	1.11	1.05	1.04	1.09	1.43	0.58	1.02	0.85	0.80
Appreciation Rate(d)		1.49	1.97	2.61	2.41	2.46	2.81	3.12	3.29	3.42	3.73	5.33	3.09	5.28	4.48	3.58

SOURCE: Canadian Petroleum Association, CPA Statistical Handbook, 1971 to 1986 editions (Calgary: Canadian Petroleum Association, 1971-1986), Reserves Section.

(a) Ultimate probable crude oil reserves for 1978. Probable ultimate recoverable crude oil reserves for 1971 to 1977. Initial established in-place crude oil reserves for 1978. Initial established crude oil reserves for 1979 to 1985.
(b) Sum of previous colum less last entry so as to include the same years as in the colum sum.
(c) Sum of colum divided by the sum of previous colum (less last entry: see note (b)).
(d) Appreciation factors compounded (multiplied) to yield total appreciation rate.

TABLE A.5

ALBERTA RAW NATURAL GAS RESERVES APPRECIATION (a)
1978-1985
(10^9 m^3)

Year of Discovery	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1970	18.3	28.6	15.9	24.7	25.2	32.4	28.4	32.1	33.5	22.4	31.5	38.2	33.4	26.1	33.2	36.7
1971	21.7	37.8	36.5	32.7	31.0	32.7	35.4	48.5	45.8	49.7	52.2	47.8	45.8	48.2	41.2	
1972	25.5	36.1	42.2	36.5	48.2	46.8	42.3	45.5	62.7	59.3	56.8	63.9	83.1	81.6		
1973	43.4	9.7	28.2	32.4	32.4	35.4	35.9	39.8	41.8	42.8	43.4	66.1	65.3			
1974	7.6	22.8	45.8	54.4	57.9	108.5	107.8	115.8	117.8	117.2	71.5	75.8				
1975	14.5	18.2	19.5	42.5	55.8	61.8	62.7	68.4	61.9	63.8	64.4					
1976	18.6	36.9	63.5	91.8	76.2	78.6	75.8	81.5	122.5	117.9						
1977	9.1	37.8	51.7	58.8	62.8	63.5	66.3	116.5	115.8							
1978	31.2	45.1	64.3	68.8	63.7	62.3	94.9	108.7								
1979	14.7	49.5	68.5	89.7	85.2	101.8	108.9									
1980	11.7	22.7	24.8	31.2	102.8	103.2										
1981	17.8	21.3	27.6	74.3	72.7											
1982	3.6	46.7	41.8	42.8												
1983	6.2	29.5	35.8													
1984	16.7	31.1														
1985	12.7															
Sum of Column	258.5	464.2	568.5	662.2	714.1	723.8	653.6	639.2	681.8	473.1	319.8	283.8	227.6	155.9	74.4	36.7
Sum of Previous Column(b)		245.8	433.1	525.5	628.2	641.4	619.8	552.7	538.5	465.2	255.2	254.6	208.8	162.3	74.3	33.2
Appreciation Factor(c)		1.89	1.29	1.26	1.15	1.13	1.05	1.16	1.12	0.98	0.98	1.11	1.09	0.96	1.00	1.11
Appreciation Rate(d)		1.89	2.44	3.08	3.55	4.00	4.22	4.87	5.44	5.31	4.76	5.28	5.75	5.57	5.57	6.16

SOURCE: Canadian Petroleum Association, CPA Statistical Handbook, 1971 to 1986 editions (Calgary: Canadian Petroleum Association, 1971-1986), Reserves Section.

(a) Ultimate probable raw natural gas reserves for 1978. Probable ultimate recoverable raw natural gas reserves for 1971 to 1977. Initial established in-place raw natural gas reserves for 1978. Initial established raw natural gas reserves for 1979 to 1985.
(b) Sum of previous column less last entry so as to include the same years as in the column sum.
(c) Sum of column divided by the sum of previous column (less last entry: see note (b)).
(d) Appreciation factors compounded (multiplied) to yield total appreciation rate.

TABLE A.6

ALBERTA
CRUDE OIL RESERVE ADDITIONS PER FOOT DRILLED (a)
1970 - 1985

YEAR	RESERVES ADDITIONS (MMB)	TOTAL EXPLORATORY FOOTAGE (1000 FEET)	TOTAL DEVELOPMENT FOOTAGE (1000 FEET)	TOTAL EXPL+DEV FOOTAGE (1000 FEET)	ADDITIONS/ EXPLORATORY (MB/FOOT)	3-YEAR AVG ADDITIONS/ EXPLORATORY (MB/FOOT)	ADDITIONS/ EXPL+DEV (MB/FOOT)	3-YEAR AVG ADDITIONS/ EXPL+DEV (MB/FOOT)
1970	257.9	1,179.1	1,457.5	2,636.7	227.2	-	101.6	-
1971	216.4	1,568.2	1,614.2	3,182.5	138.0	-	68.0	-
1972	154.7	1,088.6	2,613.4	3,702.0	142.1	166.6	41.8	67.1
1973	192.5	1,199.8	2,967.4	4,167.2	160.4	146.1	46.2	51.0
1974	68.6	1,083.0	3,009.7	4,012.6	68.4	126.3	17.1	35.0
1975	(188.5)	838.9	2,689.9	3,528.8	(215.2)	26.5	(51.2)	6.9
1976	8.2	981.6	2,361.5	3,253.1	9.1	(37.8)	2.5	(9.6)
1977	127.7	1,156.5	2,891.5	4,048.0	110.4	(15.4)	31.5	(4.1)
1978	187.4	1,794.9	3,899.4	5,694.3	104.4	83.9	32.9	24.9
1979	278.6	2,763.8	5,145.7	7,909.5	100.8	103.9	35.2	33.6
1980	(417.0)	3,111.2	6,292.5	9,403.7	(134.0)	6.4	(44.3)	2.1
1981	(35.2)	3,323.8	4,885.4	8,209.2	(10.6)	(18.9)	(4.3)	(6.8)
1982	100.0	3,774.9	5,964.6	9,739.6	26.5	(34.5)	10.3	(12.9)
1983	222.7	3,942.9	8,814.6	12,757.5	56.5	26.0	17.5	9.4
1984	353.7	5,856.3	10,113.8	15,970.1	63.5	52.0	24.0	18.4
1985	249.1	7,384.1	11,687.5	18,911.6	34.1	58.0	13.2	18.0

SOURCE: Canadian Petroleum Association, CPA Statistical Handbook, 1971 to 1986 Editions (Calgary Canadian Petroleum Association, 1971-1986), Drilling and Reserves Sections.

(a)Reserve additions equal discoveries plus revisions plus extensions.

TABLE A.7

ALBERTA
NATURAL GAS RESERVE ADDITIONS PER FOOT DRILLED (a)
1970 - 1985

YEAR	RESERVES ADDITIONS (BCF)	TOTAL EXPLORATORY FOOTAGE (1000 FEET)	TOTAL DEVELOPMENT FOOTAGE (1000 FEET)	TOTAL EXPL+DEV FOOTAGE (1000 FEET)	ADDITIONS/ EXPLORATORY (MMCF/FOOT)	3-YEAR AVG ADDITIONS/ EXPLORATORY (MMCF/FOOT)	ADDITIONS/ EXPL+DEV (MMCF/FOOT)	3-YEAR AVG ADDITIONS/ EXPL+DEV (MMCF/FOOT)
1970	1,589.2	3,108.3	1,802.3	4,910.6	511.3	-	323.6	-
1971	3,397.3	2,624.7	1,855.9	4,480.6	1,294.4	-	758.2	-
1972	(243.7)	3,837.6	2,809.6	5,847.2	(63.5)	495.6	(41.7)	311.2
1973	2,161.3	4,487.2	3,237.4	7,644.5	498.4	489.0	282.7	295.7
1974	3,584.4	4,862.7	3,517.6	7,380.2	882.3	447.1	472.9	261.1
1975	3,985.8	3,847.1	4,222.9	8,070.0	1,015.3	783.6	484.0	414.3
1976	2,454.4	5,491.8	6,985.2	12,397.0	446.9	742.0	198.0	354.6
1977	2,729.8	6,353.3	6,564.5	12,917.9	429.7	579.3	211.3	272.3
1978	4,527.3	7,316.9	6,634.7	13,951.7	618.7	586.8	324.5	247.3
1979	5,639.8	7,784.8	6,338.9	14,123.7	724.5	681.1	399.3	314.6
1980	2,698.0	9,745.1	7,947.0	17,692.1	276.9	517.8	152.5	281.1
1981	4,251.9	7,867.1	6,116.6	13,983.7	540.5	495.7	304.1	274.9
1982	2,295.5	4,670.3	4,862.5	9,532.8	491.5	414.9	240.8	224.4
1983	2,628.4	3,123.4	2,958.1	6,081.4	839.0	585.4	430.9	309.7
1984	7,967.0	3,953.4	2,961.0	6,914.4	2,015.2	1,096.7	1,152.2	571.8
1985	42.4	3,898.6	4,933.9	8,832.5	10.9	968.5	4.8	487.0

SOURCE: Canadian Petroleum Association, CPA Statistical Handbook, 1971 to 1986 Editions (Calgary Canadian Petroleum Association, 1971-1986), Drilling and Reserves Sections.

(a)Reserve additions equal discoveries plus revisions plus extensions.

TABLE A.8

INITIAL ESTABLISHED RESERVES OF CRUDE OIL AND RAW NATURAL GAS IN ALBERTA BY YEAR OF DISCOVERY AT DECEMBER 31, 1985
1970 - 1985

YEAR	RESERVES		APPRECIATION RATE		APPRECIABLE RESERVES(a)		FULLY APPRECIATED RESERVES(	
	CRUDE OIL (MB)	NAT. GAS(c) (MMCF)	CRUDE OIL	NAT. GAS	CRUDE OIL (%)	NAT. GAS (%)	CRUDE OIL (MB)	NAT. G (MM
1970	22681.0	1295096.0	1.0	1.0	0.0	34.5	22681.0	129509
1971	59526.7	1454047.5	1.0	1.0	55.2	37.4	59526.7	145404
1972	28158.8	2881997.4	1.0	1.0	0.0	47.7	28158.8	288199
1973	132117.2	2386483.1	1.0	1.0	82.7	31.3	132117.2	238648
1974	25354.2	2647260.5	1.0	1.0	13.8	53.1	25354.2	264726
1975	10000.8	2273842.9	1.0	1.0	0.0	47.7	10000.8	227384
1976	58098.3	4162049.3	1.0	1.0	49.6	58.1	58098.3	416204
1977	98195.7	4089442.3	1.0	1.0	67.1	44.5	98195.7	408944
1978	294425.5	3555731.2	1.0	1.0	88.4	31.5	294425.5	355573
1979	175857.7	3562980.1	1.0	1.0	79.8	23.2	175857.7	356290
1980	89698.8	3645889.6	1.0	1.0	41.4	7.0	89698.8	364588
1981	56444.7	2566672.4	1.7	1.8	13.6	4.3	61818.2	265496
1982	165811.7	1483923.7	2.1	2.4	64.8	3.6	284082.3	155871
1983	146992.6	1237179.9	2.3	2.9	51.1	6.5	244639.8	138997
1984	85755.1	1096181.2	2.5	3.8	24.5	0.0	117270.1	109818
1985	252642.4	449874.8	2.7	3.4	0.0	0.0	252642.4	44987

SOURCES: (1) CERI Energy Research Ltd.; and (2) Canadian Petroleum Association, CPA Statistical Handbook, as updated 1986 (Calgary: Canadian Petroleum Association, 1986), Section II, Tables 19-21.

(a) The portion of total initial established reserves by year of discovery as of December 31, 1985 reported by the Canadi Petroleum Association that are reviewed by the CPA. This includes crude oil pools larger than 300,000 cubic metres and natural gas pools larger than 600 million cubic metres. The remaining small pools are reviewed by the Alberta Energy Resources Conservation Board. All initial reserves attributed to activity in 1985 were small pool reserves which are ass to be fully appreciated.
(b) Appreciable reserves times the appreciation rate, plus unappreciable reserves.
(c) Raw natural gas. Includes pentanes plus, butane, ethane, and propane.

TABLE A.9

COMPARISON OF CRUDE OIL AND NATURAL GAS PRICES IN ALBERTA
1970-1985

	Crude Oil	Natural Gas	Crude Oil/Natural Gas
	Average Price[a] ($/bbl)	Average Price[b] ($/Mcf)	Price Ratio
1970	2.55	0.16	15.94
1971	2.83	0.16	17.69
1972	2.84	0.17	16.71
1973	3.48	0.19	18.32
1974	5.78	0.30	19.27
1975	7.26	0.62	11.71
1976	8.50	1.00	8.50
1977	10.21	1.29	7.91
1978	12.21	1.52	8.03
1979	13.18	1.73	7.62
1980	15.53	2.39	6.50
1981	18.79	2.53	7.43
1982	24.70	2.73	9.05
1983	29.69	2.94	10.10
1984	29.71	3.03	9.81
1985	34.06	2.87	11.87
Average	13.83	1.48	9.37

SOURCE: Canadian Petroleum Association, CPA Statistical Handbook, as updated to 1986 (Calgary: Canadian Petroleum Association, 1986), Section VI, Table 2.

[a]Average wellhead price, converted from $/m^3.
[b]Average wellhead/plant gate price, converted from $/10^{3}m^3.

TABLE A.10

INTENT ESTIMATION FOR ALBERTA EXPLORATION ACTIVITY
1970-1985
(percent)

Year	Successful Oil/ Total Exploratory	Successful Gas/ Total Exploratory	Exploratory Oil Intent[a]	Exploratory Oil Intent x 1.25
1970	6.8	17.8	27.5	34.4
1971	11.3	18.9	37.4	46.8
1972	6.6	23.3	22.1	27.6
1973	7.4	27.2	21.4	26.8
1974	7.4	30.2	19.8	24.8
1975	7.5	34.6	17.9	22.4
1976	7.5	46.0	14.1	17.6
1977	8.2	44.9	15.4	19.3
1978	11.2	45.6	19.7	24.6
1979	16.9	47.7	26.2	32.8
1980	16.3	50.8	24.2	30.3
1981	19.5	46.1	29.7	37.1
1982	28.8	35.6	44.7	55.9
1983	33.6	26.6	55.8	69.8
1984	33.4	22.5	59.7	74.6
1985	35.7	19.1	65.2	81.5

SOURCE: Canadian Petroleum Association, CPA Statistical Handbook, as updated to 1986 (Calgary: Canadian Petroleum Association, 1986), Section 1, Tables 5-5A.

[a]Successful oil/total successful.

TABLE A.11

LONG-TERM BOND/INDUSTRIALS YIELD INDEX[a]
1970-1985

Year	Index
1970	9.18
1971	8.35
1972	8.30
1973	8.47
1974	10.17
1975	10.76
1976	10.47
1977	9.71
1978	10.02
1979	10.88
1980	13.24
1981	16.22
1982	15.87
1983	12.84
1984	13.57
1985	11.73

SOURCE: McLeod, Young, Weir Limited.

[a]Twelve month average of McLeod, Young, Weir 40 bond long-term index/10 industrials yield index.

APPENDIX B

CRUDE OIL EQUIVALENT FINDING COST RESULTS

TABLE B.1

ALBERTA BASE CASE
CRUDE OIL EQUIVALENT
FINDING COSTS
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	8.30			
1971	5.90			
1972	3.83	5.48		
1973	3.43	4.15		
1974	4.26	3.81	4.65	
1975	4.83	4.00	4.29	
1976	3.13	3.86	3.76	4.32
1977	5.33	4.38	4.17	4.28
1978	4.73	4.45	4.47	4.26
1979	7.13	5.67	5.00	4.81
1980	8.72	6.63	5.75	5.54
1981	8.04	8.11	6.66	6.00
1982	4.62	7.31	6.57	5.90
1983	5.44	6.12	6.93	6.25
1984	10.73	6.25	7.34	6.74
1985	9.55	8.11	7.35	7.54

SOURCE: CERI Energy Research Ltd.

TABLE B.2

ALBERTA BASE CASE
CRUDE OIL EQUIVALENT
FINDING COSTS
BY EXPENDITURE TYPE
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

	EXPLORATION			
YEAR	GEOLOGICAL AND GEOPHYSICAL	DRILLING	LAND PURCHASE AND RENTALS	TOTAL EXPLORATION
1970	1.79	2.72	3.78	8.30
1971	1.82	1.91	2.97	5.90
1972	0.69	1.41	1.72	3.83
1973	0.55	1.37	1.51	3.43
1974	0.98	1.58	1.70	4.26
1975	0.85	1.66	2.32	4.83
1976	0.57	1.28	1.28	3.13
1977	0.74	1.68	2.90	5.33
1978	0.78	1.84	2.11	4.73
1979	0.88	2.96	3.29	7.13
1980	1.28	4.36	3.16	8.72
1981	1.21	5.20	2.43	8.84
1982	0.80	2.66	1.15	4.62
1983	1.04	2.83	1.57	5.44
1984	2.12	5.87	3.55	10.73
1985	1.68	4.55	3.48	9.55

SOURCE: CERI Energy Research Ltd.

TABLE B.3 - SENSITIVITY 1
CRUDE OIL EQUIVALENCE AT 6 MCF : 1 BARREL

ALBERTA
CRUDE OIL EQUIVALENT
FINDING COSTS
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	5.50			
1971	4.18			
1972	2.50	3.69		
1973	2.51	2.89		
1974	2.80	2.60	3.18	
1975	3.13	2.78	2.91	
1976	2.07	2.54	2.53	2.92
1977	3.63	2.92	2.82	2.89
1978	3.59	3.13	3.08	2.95
1979	5.14	4.09	3.56	3.37
1980	5.97	4.80	4.04	3.84
1981	6.84	5.66	4.72	4.18
1982	3.82	5.32	4.83	4.22
1983	4.49	4.76	5.14	4.59
1984	8.37	5.10	5.53	5.04
1985	8.76	6.81	5.87	5.74

SOURCE: CERI Energy Research Ltd.

TABLE B.4 - SENSITIVITY 2
CRUDE OIL EQUIVALENCE AT 18 MCF : 1 BARREL

ALBERTA
CRUDE OIL EQUIVALENT
FINDING COSTS
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	14.07			
1971	9.00			
1972	6.94	9.26		
1973	4.97	6.56		
1974	7.58	6.28	7.60	
1975	8.92	6.71	7.12	
1976	5.48	6.89	6.41	7.27
1977	8.82	7.56	6.99	7.17
1978	6.47	6.90	7.18	6.84
1979	10.59	8.40	7.93	7.52
1980	14.25	9.77	8.91	8.80
1981	14.35	12.76	10.18	9.47
1982	5.61	10.65	9.45	8.89
1983	6.64	8.85	9.81	8.99
1984	14.10	7.73	10.16	9.42
1985	10.34	9.67	9.31	10.26

SOURCE: CERI Energy Research Ltd.

TABLE B.5 - SENSITIVITY 3
CRUDE OIL EQUIVALENCE AT YEARLY RATES

ALBERTA
CRUDE OIL EQUIVALENT
FINDING COSTS
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	13.04			
1971	9.83			
1972	6.49	8.04		
1973	5.84	6.46		
1974	7.97	6.28	7.53	
1975	5.90	6.09	6.60	
1976	2.85	4.47	4.86	5.75
1977	4.61	4.10	4.60	5.06
1978	4.31	3.92	4.45	4.65
1979	6.13	4.99	4.64	4.84
1980	6.48	5.56	4.92	5.12
1981	7.24	6.51	5.60	5.23
1982	4.55	6.08	5.64	5.12
1983	5.59	5.76	6.02	5.48
1984	10.96	6.29	6.51	5.98
1985	9.88	8.34	7.10	6.75

SOURCE: CERI Energy Research Ltd.

TABLE B.6 - SENSITIVITY 4
NO RESERVES APPRECIATION

ALBERTA
CRUDE OIL EQUIVALENT
FINDING COSTS
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	8.30			
1971	5.90			
1972	3.83	5.48		
1973	3.43	4.15		
1974	4.26	3.81	4.65	
1975	4.83	4.08	4.29	
1976	3.13	3.86	3.76	4.32
1977	5.33	4.38	4.17	4.28
1978	4.73	4.45	4.47	4.26
1979	7.13	5.67	5.08	4.81
1980	8.72	6.63	5.75	5.54
1981	9.24	8.29	6.70	6.82
1982	6.42	8.22	6.97	6.15
1983	7.67	7.79	7.83	6.76
1984	12.40	8.36	8.65	7.42
1985	9.55	9.62	8.81	8.42

SOURCE: CERI Energy Research Ltd.

TABLE B.7 - SENSITIVITY 5
50 % OF LAND EXPENDITURES

ALBERTA
CRUDE OIL EQUIVALENT
FINDING COSTS
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	6.41			
1971	4.41			
1972	2.96	4.19		
1973	2.68	3.18		
1974	3.41	2.99	3.61	
1975	3.67	3.18	3.31	
1976	2.49	3.04	2.95	3.36
1977	3.88	3.30	3.19	3.27
1978	3.68	3.39	3.43	3.28
1979	5.48	4.31	3.88	3.70
1980	7.14	5.23	4.48	4.31
1981	7.63	6.59	5.28	4.74
1982	4.84	6.18	5.35	4.73
1983	4.66	5.29	5.73	5.04
1984	8.96	5.34	6.21	5.53
1985	7.85	6.78	6.23	6.24

SOURCE: CERI Energy Research Ltd.

TABLE B.8 - SENSITIVITY 6
ALTERNATIVE RESERVES DATA BASE (a)

ALBERTA
CRUDE OIL EQUIVALENT
FINDING COSTS
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	9.26			
1971	6.15			
1972	3.88	5.72		
1973	3.65	4.32		
1974	4.83	3.85	4.77	
1975	6.21	4.36	4.51	
1976	3.66	4.32	4.88	4.68
1977	5.07	4.75	4.41	4.49
1978	4.52	4.48	4.57	4.38
1979	6.68	5.37	5.15	4.86
1980	7.30	6.85	5.51	5.40
1981	7.01	6.99	6.01	5.73
1982	3.91	6.85	5.80	5.46
1983	4.32	4.97	5.86	5.51
1984	5.94	4.65	5.68	5.62
1985	5.90	5.36	5.34	5.88

SOURCES: (1) Alberta Energy Resources Conservation Board, "Alberta Gas Reserve Trends," ERCB Report No. ST 86-47 (Calgary: Alberta Energy Resources Conservation Board, 1985); and (2) CERI Energy Research Ltd.

(a) Pentanes plus, butane, ethane, and propane reserves not included.

APPENDIX C

EXTENSION CASE RESULTS

TABLE C.1 - EXTENSION 1

ALBERTA
CRUDE OIL FINDING COSTS
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	16.14			
1971	7.94			
1972	13.71	10.89		
1973	2.10	4.84		
1974	10.20	4.57	6.35	
1975	21.77	4.58	6.00	
1976	4.34	8.12	5.25	6.52
1977	4.78	5.76	4.55	5.55
1978	2.13	2.93	3.73	3.70
1979	5.91	3.74	4.00	3.94
1980	11.24	4.78	4.74	5.16
1981	14.63	9.02	5.63	5.76
1982	3.27	6.52	4.98	4.93
1983	4.87	5.12	5.93	4.94
1984	12.79	5.61	6.94	5.68
1985	7.41	7.43	6.66	6.09

SOURCE: CERI Energy Research Ltd.

ALBERTA
NATURAL GAS FINDING COSTS
1970 - 1985
(1985 CONSTANT DOLLARS PER THOUSAND CUBIC FEET)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	0.75			
1971	0.54			
1972	0.34	0.46		
1973	0.44	0.42		
1974	0.48	0.39	0.45	
1975	0.44	0.42	0.42	
1976	0.32	0.37	0.38	0.42
1977	0.58	0.45	0.44	0.43
1978	0.72	0.53	0.50	0.47
1979	0.82	0.70	0.58	0.54
1980	0.87	0.80	0.65	0.60
1981	0.81	0.83	0.75	0.65
1982	0.74	0.82	0.80	0.67
1983	0.68	0.76	0.80	0.74
1984	0.92	0.77	0.81	0.79
1985	2.22	1.01	0.87	0.86

SOURCE: CERI Energy Research Ltd.

TABLE C.3 - EXTENSION 1
OIL INTENT * 1.25

ALBERTA
CRUDE OIL FINDING COSTS
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	20.20			
1971	9.93			
1972	17.12	13.62		
1973	2.63	6.86		
1974	12.78	5.72	7.55	
1975	27.24	5.63	7.60	
1976	5.41	10.15	6.56	8.15
1977	5.99	7.21	5.70	6.95
1978	2.66	3.67	4.66	4.63
1979	7.40	4.68	5.10	4.93
1980	14.07	5.98	5.94	6.46
1981	18.27	11.29	7.85	7.20
1982	4.09	8.16	6.22	6.17
1983	6.10	6.41	7.41	6.18
1984	15.99	7.01	8.68	7.10
1985	9.26	9.28	8.33	8.61

SOURCE: CERI Energy Research Ltd.

TABLE C.4 - EXTENSION 1
OIL INTENT * 1.25

ALBERTA
NATURAL GAS FINDING COSTS
1970 - 1985
(1985 CONSTANT DOLLARS PER THOUSAND CUBIC FEET)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	0.67			
1971	0.46			
1972	0.31	0.44		
1973	0.41	0.38		
1974	0.37	0.36	0.41	
1975	0.42	0.40	0.38	
1976	0.31	0.35	0.35	0.39
1977	0.55	0.42	0.41	0.40
1978	0.68	0.50	0.47	0.44
1979	0.74	0.65	0.54	0.51
1980	0.80	0.74	0.60	0.56
1981	0.72	0.76	0.69	0.60
1982	0.59	0.73	0.72	0.62
1983	0.46	0.62	0.71	0.67
1984	0.58	0.54	0.68	0.69
1985	1.18	0.62	0.65	0.71

SOURCE: CERI Energy Research Ltd.

TABLE C.5 - EXTENSION 2

ALBERTA
LAGGED EXPENDITURE FINDING COSTS (a)
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970				
1971				
1972	4.03			
1973	3.52			
1974	3.82	3.77		
1975	4.62	3.91		
1976	2.66	3.47	3.58	
1977	3.31	3.32	3.43	
1978	3.28	3.11	3.37	3.46
1979	6.28	4.24	3.96	3.98
1980	7.80	5.52	4.58	4.51
1981	11.71	8.16	5.98	5.32
1982	7.41	8.72	6.71	5.64
1983	6.59	8.39	7.73	6.18
1984	9.76	7.62	8.41	6.93
1985	8.73	8.69	8.63	8.82

SOURCE: CERI Energy Research Ltd.

(a) Land expenditures and geological and geophysical expenditures lagged by two years and one year, respectively.

APPENDIX D

PREFERRED CASE RESULTS

TABLE D.1

ALBERTA
PREFERRED CASE CRUDE OIL FINDING COSTS (a)
(LOW CASE)
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	15.59			
1971	7.43			
1972	13.26	10.39		
1973	2.05	4.63		
1974	10.23	4.49	6.13	
1975	20.70	4.40	5.85	
1976	4.31	7.98	5.13	6.30
1977	4.36	5.43	4.37	5.31
1978	2.07	2.80	3.58	3.57
1979	5.69	3.57	3.91	3.80
1980	11.52	4.72	4.64	5.05
1981	15.76	9.20	5.63	5.74
1982	3.58	6.95	5.12	5.01
1983	5.21	5.53	6.19	5.08
1984	13.35	5.97	7.36	5.90
1985	7.61	7.75	7.03	7.17

(a) Based on only fifty percent of land expenditures. Estimated intent # 1.25.

TABLE D.2

ALBERTA
PREFERRED CASE CRUDE OIL FINDING COSTS (a)
(HIGH CASE)
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	20.20			
1971	9.93			
1972	17.12	13.62		
1973	2.63	6.06		
1974	12.78	5.72	7.95	
1975	27.24	5.63	7.60	
1976	5.41	10.15	6.56	8.15
1977	5.99	7.21	5.70	6.95
1978	2.66	3.67	4.66	4.63
1979	7.40	4.68	5.10	4.93
1980	14.07	5.98	5.94	6.46
1981	18.27	11.29	7.85	7.20
1982	4.09	8.16	6.22	6.17
1983	6.10	6.41	7.41	6.18
1984	15.99	7.01	8.68	7.10
1985	9.26	9.28	8.33	8.61

(a) Estimated intent * 1.25.

TABLE D.3

ALBERTA
PREFERRED CASE NATURAL GAS FINDING COSTS (a)
(LOW CASE)
1970 - 1985
(1985 CONSTANT DOLLARS PER THOUSAND CUBIC FEET)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	0.52			
1971	0.35			
1972	0.24	0.33		
1973	0.32	0.29		
1974	0.30	0.28	0.32	
1975	0.32	0.31	0.30	
1976	0.24	0.28	0.28	0.30
1977	0.40	0.32	0.32	0.31
1978	0.52	0.38	0.36	0.34
1979	0.57	0.50	0.41	0.39
1980	0.65	0.58	0.47	0.44
1981	0.62	0.62	0.55	0.47
1982	0.51	0.61	0.58	0.49
1983	0.40	0.54	0.58	0.53
1984	0.49	0.47	0.57	0.56
1985	0.97	0.52	0.56	0.58

(a) Based on only fifty percent of land expenditures. Estimated intent * 1.25.

TABLE D.4

ALBERTA
PREFERRED CASE NATURAL GAS FINDING COSTS (a)
(HIGH CASE)
1970 - 1985
(1985 CONSTANT DOLLARS PER THOUSAND CUBIC FEET)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970	0.67			
1971	0.46			
1972	0.31	0.44		
1973	0.41	0.38		
1974	0.37	0.36	0.41	
1975	0.42	0.40	0.38	
1976	0.31	0.35	0.35	0.39
1977	0.35	0.42	0.41	0.40
1978	0.68	0.50	0.47	0.44
1979	0.74	0.65	0.54	0.51
1980	0.80	0.74	0.68	0.56
1981	0.72	0.76	0.69	0.60
1982	0.59	0.73	0.72	0.62
1983	0.46	0.62	0.71	0.67
1984	0.58	0.54	0.68	0.69
1985	1.18	0.62	0.65	0.71

(a) Estimated intent * 1.25.

TABLE D.5

ALBERTA
PREFERRED CASE LAGGED CRUDE OIL FINDING COSTS (a)
(LOW CASE)
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970				
1971				
1972	16.91			
1973	2.56			
1974	9.54	5.18		
1975	22.39	4.80		
1976	4.33	7.99	5.73	
1977	3.15	4.82	4.24	
1978	1.45	2.14	2.97	3.33
1979	4.54	2.69	3.14	3.25
1980	18.41	3.86	3.80	4.25
1981	18.85	8.71	5.80	5.18
1982	3.85	7.22	4.82	4.66
1983	4.92	5.78	6.81	4.72
1984	11.74	5.69	7.18	5.48
1985	6.99	7.87	6.83	6.76

(a) Based on only fifty percent of land expenditures. Estimated intent * 1.25. Land expenditures and geological and geophysical expenditures lagged by two years and one year, respectively.

TABLE D.6

ALBERTA
PREFERRED CASE LAGGED CRUDE OIL FINDING COSTS (a)
(HIGH CASE)
1970 - 1985
(1985 CONSTANT DOLLARS PER BARREL)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970				
1971				
1972	22.27			
1973	3.59			
1974	12.17	6.93		
1975	28.78	6.39		
1976	5.49	10.20	7.55	
1977	3.86	6.06	5.58	
1978	1.63	2.54	3.62	4.22
1979	5.26	3.13	3.73	3.98
1980	11.99	4.43	4.43	5.03
1981	22.38	10.35	5.92	6.19
1982	4.75	8.74	5.76	5.58
1983	5.73	7.00	7.17	5.61
1984	13.31	6.67	8.49	6.45
1985	7.99	8.10	8.03	7.92

(a) Estimated intent * 1.25. Land expenditures and geological and and geophysical expenditures lagged by two years and one year, respectively.

TABLE D.7

ALBERTA
PREFERRED CASE LAGGED NATURAL GAS FINDING COSTS (a)
(LOW CASE)
1970 - 1985
(1985 CONSTANT DOLLARS PER THOUSAND CUBIC FEET)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970				
1971				
1972	0.23			
1973	0.30			
1974	0.26	0.26		
1975	0.31	0.29		
1976	0.21	0.25	0.25	
1977	0.29	0.26	0.27	
1978	0.42	0.30	0.29	0.29
1979	0.57	0.42	0.35	0.34
1980	0.61	0.53	0.41	0.38
1981	0.79	0.64	0.51	0.44
1982	0.90	0.73	0.62	0.48
1983	0.61	0.78	0.67	0.55
1984	0.53	0.70	0.69	0.61
1985	1.11	0.66	0.76	0.67

(a) Based on only fifty percent of land expenditures. Estimated intent * 1.25. Land expenditures and geological and geophysical expenditures lagged by two years and one year, respectively.

TABLE D.8

ALBERTA
PREFERRED CASE LAGGED NATURAL GAS FINDING COSTS (a)
(HIGH CASE)
1970 - 1985
(1985 CONSTANT DOLLARS PER THOUSAND CUBIC FEET)

YEAR	YEARLY	THREE YEAR MOVING AVG.	FIVE YEAR MOVING AVG.	SEVEN YEAR MOVING AVG.
1970				
1971				
1972	0.30			
1973	0.37			
1974	0.33	0.33		
1975	0.38	0.36		
1976	0.25	0.31	0.32	
1977	0.34	0.31	0.32	
1978	0.48	0.35	0.35	0.35
1979	0.72	0.51	0.43	0.41
1980	0.73	0.64	0.49	0.46
1981	1.00	0.80	0.63	0.54
1982	1.27	0.93	0.77	0.60
1983	0.85	1.04	0.86	0.69
1984	0.66	0.96	0.89	0.77
1985	1.35	0.86	1.00	0.86

(a) Estimated intent + 1.25. Land expenditures and geological and geophysical expenditures lagged by two years and one year, respectively.

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